Informatics for Accountancy

A practical guide to accounting, reporting, auditing, and analysis in a digital environment; achieving digital literacy

By

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"I skate to where the puck is going, not to where it has been."
Legendary Canadian hockey star Wayne Gretzky

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1. Introduction

A paradigm shift is occurring. The territory is changing. A new map is necessary. Trying to use your old map to understand the new territory will be unsatisfying.

This shift is caused by the difference between how "realspace" (the real world, analog) and "cyberspace" (the internet, digital) operate.

Probably the biggest mistake one can make is misunderstanding the notion of intelligence[1] and grouping "human intelligence" and "machine intelligence" together.

I would contend that it is a fool's errand to try and compare machine-intelligence to human-intelligence. They are not even in the same ballpark and they won't be for a long time, if ever. The notion of "superintelligence" in computers is a fantasy. Computers are nowhere close to achieving superintelligence which I would consider as being human-level intelligence or higher levels of intelligence beyond the capabilities of humans. If you are interested in this topic, I would highly recommend the book *The Myth of Artificial Intelligence* which analyzes these ideas in great detail in a very approachable way.

That is not to say that nothing will change. Plenty will change. But I look at what is going on differently than most others[2]. I define intelligence as effective "human-task" performance. Basically a "machine" (e.g. computer or other apparatus) for performing human tasks agreed to by a known group of stakeholders and the system has known goals and objectives. In essence, this is a formal system with specific boundaries and the system is blind to something not covered by the rules of that specific defined system. This will be a combination of symbolic systems and machine learning, using the right tool for the job.

Increasing efficiency or productivity without maintaining quality or increasing quality is useless.

Lawrence Lessig explains this difference between "realspace" and "cyberspace" in his book, *Code and Other Laws of Cyberspace*[3]. The book outlines what is called the *Theory of Regulation* or the *Pathetic Dot Theory*[4]; the four forces that constrain our actions:

- **Laws and regulations**: The law threatens sanction if rules are not obeyed.
- **Norms**: Social norms are enforced by the community.
- **Markets**: Supply and demand (e.g. better, faster, cheaper) set a price on various items or behaviors.
- **Architecture**: The "social architecture" whether natural (made by nature) or designed (manmade) constrain our actions.

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[1] *Intelligence*, https://digitalfinancialreporting.blogspot.com/2024/04/intelligence.html
[2] *Seeing Digital Financial Reporting Differently*, https://digitalfinancialreporting.blogspot.com/2023/12/seeing-digital-financial-reporting.html
[3] Wikipedia, *Code and Other Laws of Cyberspace*, https://en.wikipedia.org/wiki/Code_and_Other_Laws_of_Cyberspace
[4] Wikipedia, *Pathetic dot Theory*, https://en.wikipedia.org/wiki/Pathetic_dot_theory

Changes must be considered within the context of all four of the above constraints. You cannot simply consider one constrain and ignore others; all four must be considered together.

1.1. Digital Proficiency

Proficiency is the capability, skill, and knowledge that you might have for doing something. There are general levels of proficiency: literacy, fluency, mastery. Proficiency is a progression.

Digital proficiency is the capability to understand the change between "realspace" and "cyberspace". One key benefit of digital proficiency is that it helps you understand the true limitations of technology.

"Digital" is a thing, it is causing many changes, and not understanding what will change, why, and how is becoming increasingly risky. Accountants must choose what type of "cyberspace" they want. The great transmutation to digital[5], things like algorithmic regulation and digital twins, will cause the world to work in different ways than it has worked in the past. To achieve this, you need to understand not just your domain of knowledge; but also, technology as it might be applied to your domain of knowledge. But also, efficiency without quality is useless.

To choose, accountants need to have digital proficiency.

This document provides a bit of theory for grounding; but focuses on practical application.

1.2. Informatics

There is no one formal definition of informatics as far as I can tell. This is one definition that I synthesized from other definitions that I like:

Informatics[6] relates to the intersection of information, people, and technology and the practical application of computational systems; understanding how people will "live" in the digital realm within some specific area of knowledge that makes sense to users of that technology.

Analogy to a chef: Similar to how a chef transforms a recipe using kitchen equipment into an unforgettable meal; informatics transforms the use of information and knowledge into a successful experience.

Analogy to architect: Similar to an architect that transforms a building into a livable space by placing doors, windows, and utilities with functionality and ease; informatics improves "digital livability".

Informatics will be explained in more detail in a later section.

[5] Charles Hoffman, CPA, *The Great Transmutation*, https://xbrlsite.azurewebsites.net/2022/Library/TheGreatTransmutation.pdf
[6] Wikipedia, *Informatics*, https://en.wikipedia.org/wiki/Informatics

1.3. Accountancy

Accountancy[7] as I will use the term is defined as the professional practice of accounting, reporting, auditing, and analysis. This includes financial, managerial or cost, and tax accounting.

New types of tools are not only possible, but necessary to perform the work related to the professional practice of accounting, reporting, auditing, and analysis. This includes the areas of financial, management, and tax.

1.4. Computational Systems

A system[8] is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Logic is thinking according to a set of consistent and coherence rules. A logical system (a.k.a. formal system, axiomatic system, conceptual model) enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important common models, structures, and statements for capturing meaning or representing a shared understanding of and knowledge in some universe of discourse.

A computation is any type of calculation or calculus that includes both arithmetical and non-arithmetical steps and which follows a well-defined model or algorithm. An algorithm is a finite sequence of well-defined instructions, typically to solve a class of problems or to perform a computation. Algorithms are always unambiguous and are used as specifications for performing calculations, data processing, automated reasoning, and other tasks within a system.

The algorithmic economy is a term used to describe the increasing role that algorithms and artificial intelligence (AI) play in modern economic systems[9].

For example, a general purpose financial report is a complicated logical or computational system[10] invented by humans to achieve a specific purpose which is to exchange information about the financial status and financial performance of an economic entity.

1.5. Technology

Accounting, which has existed for about 7,000 years[11], even before the creation of formal number systems, is constantly evolving. It would be hard to imagine the large multinational corporation without this universal technology of accountability[12].

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[7] Accounting Tools, *Accountancy*, https://www.accountingtools.com/articles/what-is-accountancy.html
[8] *System Thinking*, https://digitalfinancialreporting.blogspot.com/2023/09/systems-thinking.html
[9] Ian Kahn, What is the Algorithmic Economy?, https://www.iankhan.com/what-is-the-algorithmic-economy/
[10] *Logical Systems for Business Professionals*, https://digitalfinancialreporting.blogspot.com/2023/09/logical-systems-for-business.html
[11] Wikipedia, History of Accounting, retrieved June 10, 2017, https://en.wikipedia.org/wiki/History_of_accounting
[12] Universal Technology of Accountability, https://digitalfinancialreporting.blogspot.com/2023/02/universal-technology-for-accountability.html

Accounting is about to go through another significant phase in that evolution process. Tools will be modernized to be more effective in the information age.

There are three specific key, new enabling technologies that, building on medieval traditions, can be leveraged to significantly improve and modernize accountancy. Those technologies will transition into the mainstream over the coming years. Those three technologies are[13]:

- **Knowledge graphs or structured information** such as global standard XBRL-based structured digital financial reports and other such machine-readable information formats for exchanging information[14] commonly referred to as knowledge graphs[15]. There are also other structured information formats.
- **Knowledge-based systems** and other applications of artificial intelligence; at first primarily rules-based systems (deductive reasoning) and then ultimately patterns-based systems (i.e. machine learning; inductive reasoning, abductive reasoning)[16].
- **Digital distributed ledgers** using blockchain, hashgraph, hyperledger, or other such technologies that enable the creation of immutable public or private ledgers[17] or public databases enhanced by smart contracts[18] and logic contracts[19].

Trying to understand these changes from the perspective of today's accounting, reporting, auditing, and analysis practices will not help you understand these coming changes appropriately. A change in perspective is necessary.

These new technologies build upon and further enhance other existing technologies such as the computer and the internet.

1.6. Fourth Industrial Revolution

Accountancy evolves. Accounting transactions were documented using physical objects before writing was invented. Clay tablets were employed at one point. Then papyrus. Then paper. Then e-paper such as PDF and HTML. Now comes machine-readable information.

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[13] Charles Hoffman, CPA, *Modernizing Accounting and Auditing: Three Technology Trends*, http://xbrl.squarespace.com/journal/2017/5/27/modernizing-accounting-and-auditing-three-technology-trends.html

[14] Charles Hoffman, CPA, *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/Library/SpecialTheoryOfSemanticCommunicationOfFinancialInformation.pdf

[15] *Knowledge Assembly*, https://digitalfinancialreporting.blogspot.com/2023/08/knowledge-assembly.html

[16] Charles Hoffman, CPA, *Artificial Intelligence and Knowledge Engineering in a Nutshell*, http://xbrlsite.azurewebsites.net/2019/Library/KnowledgeEngineeringInNutShell.pdf

[17] Charles Hoffman, CPA, Digital Distributed Ledgers, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part01_Chapter02.71_DistributedLedgers.pdf

[18] Wikipedia, *Smart Contracts*, https://en.wikipedia.org/wiki/Smart_contract

[19] *Logical Contracts*, http://logicalcontracts.com/

Each of the four largest public accounting firms in one way or another tell their clients to get ready for big changes caused by the fourth industrial revolution[20]. One of those firms, Deloitte, articulates a particularly good vision which they refer to as *The Finance Factory*[21]. Deloitte envisions things like paperless core finance processes with a continuous, if not real time, financial close.

Another public accounting firm, PWC, predicts that global GDP will be 14% higher in 2030 as a result of artificial intelligence – the equivalent of an additional $15.7 trillion increase in GDP which makes AI the biggest commercial opportunity in today's economy[22]. PWC is investing $3 billion to upskill their staff[23].

Accountants, don't under estimate the value of double-entry bookkeeping and the other processes, procedures, and techniques employed to make sure that everything "ticks and ties" and "cross casts and foots". These useful techniques, even perhaps better referred to as ingrained medieval traditions, should make their way into these new modern accounting techniques and methods. These successful and important medieval techniques are still very relevant even in the digital age.

Accounting, reporting, auditing, and analysis are going through a great upheaval, transitioning from an analog-based system used during the industrial age to a digital-based system as we become a knowledge economy[24].

1.7. Area of Knowledge

An **area of knowledge** is a highly organized socially constructed aggregation of shared knowledge for a distinct subject matter. An area of knowledge has a specialized insider vocabulary (i.e. jargon), norms, underlying assumptions (axioms, theorems, constraints, assertions, restrictions), and perhaps some persistent open questions that have not necessarily been resolved within that area of knowledge (i.e. flexibility is necessary, change occurs).

Accountancy is an area of knowledge. You can explain aspects of the accounting area of knowledge, such as the nature of a financial report, using a logical theory which describes a logical model. A logical theory can be tested and proven by providing a proof. When all the details are worked out, you have a best practice based proven method.

Knowledge can be represented in human-readable form, in machine-readable form, or in a machine-readable form that can be effectively converted into human-readable form.

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[20] Charles Hoffman, CPA, *Adapting to Changes Caused by the Fourth Industrial Revolution*, http://xbrl.squarespace.com/journal/2019/8/4/adapting-to-changes-caused-by-the-fourth-industrial-revoluti.html

[21] Charles Hoffman, CPA, *Deloitte's Vision: The Finance Factory*, http://xbrl.squarespace.com/journal/2019/2/20/deloittes-vision-the-finance-factory.html

[22] Charles Hoffman, CPA, *Artificial Intelligence Done Right*, http://xbrl.squarespace.com/journal/2019/10/19/artificial-intelligence-done-right.html

[23] Charles Hoffman, CPA, *PWC to Invest $3 Billion in Upgrading Skills*, http://xbrl.squarespace.com/journal/2019/10/12/pwc-to-invest-3-billion-in-upgrading-skills.html

[24] Arthur Levine, Scott van Pelt, *The Great Upheaval*, https://www.amazon.com/Great-Upheaval-Educations-Present-Uncertain/dp/1421442574/

You can think about an area of knowledge as being characterized in a spectrum with two extremes:

- **Kind area of knowledge**: clear information, clear rules, lots of patterns, lots of rules, repetitive patterns, and typically unchanging tasks.
- **Wicked area of knowledge**: obscure data, few or no rules, constantly changing tasks, and abstract ideas.

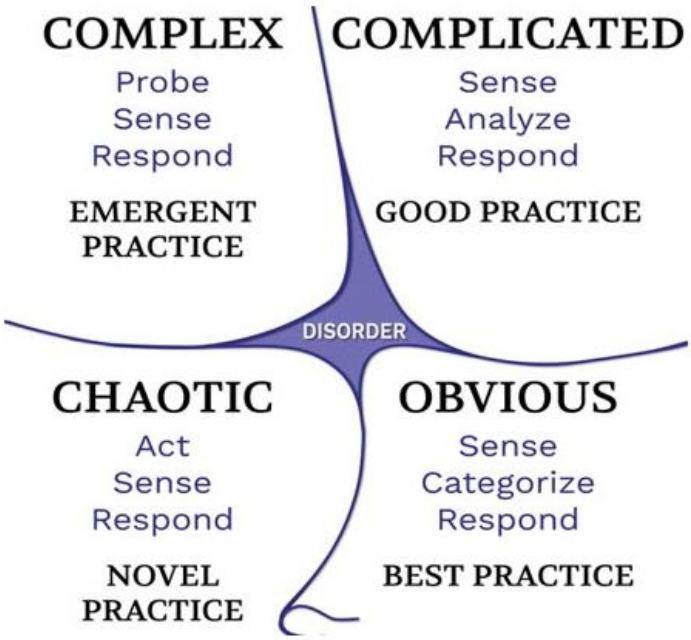
An area of knowledge can have aspects of both extremes, but tends to lean toward one side of the spectrum or the other. Financial accounting and reporting tend to lean more toward the "kind" end in many ways, particularly the quantitative aspects of accounting and reporting. The qualitative aspects may be more in the wicked side of the spectrum.

Another term for area of knowledge is a knowledge domain or simply domain. Subject matter experts, or SMEs, are those that have skills and expertise within an area of knowledge.

1.8. Norms

Difference systems have different levels of complexity. Systems can also be ordered or disordered. The Cynefin Framework[25] is a conceptual framework that helps you understand the dynamics that are at work within different types of systems. The framework was created in 1999 by David Snowden of IBM Global Services to help IBM to manage intellectual capital.

The following graphic helps one understand and categorize the different levels of complexity: simple, complicated, complex, and chaotic. The graphic also helps one understand the difference between disorder and order.



[25] Cynefin Framework, http://xbrl.squarespace.com/journal/2021/3/21/cynefin-framework.html

The video *Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements*[26] provides an excellent walk through of these ideas.

Different skill sets are necessary to be able to create simple, complicated, and complex systems that work effectively.

The majority of accounting and reporting knowledge tends to be simple and complicated per the definitions of the Cynefin framework.

1.9. Sensemaking

Sensemaking[27] is the process of determining the deeper meaning or significance or essence of the collective experience for those within an area of knowledge. System stakeholders need to be in agreement as to an undisputed core knowledge, a.k.a. norms, of a system.

The Cynefin Framework[28] provides a tool for understanding and categorizing knowledge. Per the Cynefin Framework, knowledge can be categorized as being:

- Best practice (obvious)
- Good practice (only obvious if you have the right skills and experience)
- Emergent practice (tends to have more alternatives, tend to have to have more skills and experience, then can use principles to group alternatives)
- Novel practice (tends to be unique, but describable)

Knowledge of facts is distinct from opinion or guesswork by virtue of justification or proof. Knowledge is objective. Opinions and guesswork are subjective.

Sensemaking relates to sorting out the puzzle pieces[29] of an area of knowledge so that the area of knowledge can be made digital.

One example in our area of knowledge of accountancy is the general purpose financial report; we are talking about certain specific knowledge, the facts that make up that knowledge, being able to create a proof to show the knowledge graph system is complete, consistent, and precise; and all of this logic being put into a form readable by a machine and reach a conclusion as to whether the information in the knowledge graph is functioning properly.

Effectively, a machine can read that knowledge and mimic understanding of that knowledge represented in a knowledge graph and the information available to both a human reader and a machine reader would be the same and therefore the human and machine should reach the same conclusion.

1.10. Complexity

The *Law of Conservation of Complexity* states that, "Every software application has an inherent amount of irreducible or essential complexity. The question is who will

[26] Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements, https://www.youtube.com/watch?v=L5fnxahydXM
[27] Sensemaking, http://xbrl.squarespace.com/journal/2021/11/18/sensemaking.html
[28] Wikipedia, Cynefin Framework, https://en.wikipedia.org/wiki/Cynefin_framework
[29] Puzzle Pieces of Digital Financial Reporting, https://digitalfinancialreporting.blogspot.com/2023/11/puzzle-pieces-of-digital-financial.html

have to deal with that complexity: the application developer, the platform developer that the software runs on, or the software user."

Irreducible Complexity (a.k.a. essential complexity) is a term used to describe a characteristic of complex systems whereby the complex system needs all of its individual component systems in order to effectively function. (To effectively satisfy the aim of the system; meet the goals/objectives of the stakeholders of the system.)

Simple means that all accidental complexity that can be removed from a system, has been removed from the system; only essential complexity remains.

Simplistic means that essential complexity has been removed from a system in order to reduce overall system complexity and therefore the system cannot satisfy the aim or goals or objectives of the system.

Complexity can be broken down into two parts[30]: essential complexity and accidental complexity.

A *kludge*[31] is an engineering/computer science term that defines what is best described as a workaround or quick-and-dirty solution that contains excessive accidental complexity and is typically clumsy, inelegant, inefficient, difficult to extend and hard to maintain; but it gets the job done and includes all the necessary essential complexity. The nautical term for this is jury rigging[32].

By contrast, elegance is beauty and gracefulness that shows unusual effectiveness and simplicity in a system that is free from accidental complexity.

1.11. Atomic Design Methodology

The Atomic Design Methodology[33] is an approach that can be used to make software applications easier to use.

1.12. Generalized versus Specialized Systems

Everything in life is a tradeoff. Generalized systems are very flexible; but they are harder to make use of. Specialized systems are less flexible; but they can be significantly easier to make use of.

Specializing a system to one area of knowledge and the proper management of complexity can yield powerful software for that specific area of knowledge that is elegant and easy to use.

1.13. Lean Six Sigma

Lean Six Sigma[34] is a discipline that combines the problem-solving methodologies and quality enhancement techniques of Six Sigma with the process improvement tools and efficiency concepts of Lean Manufacturing. Born in the manufacturing

[30] Wikipedia, No Silver Bullet, https://en.wikipedia.org/wiki/No_Silver_Bullet#Summary
[31] Wikipedia, Kludge, https://en.wikipedia.org/wiki/Kludge
[32] Wikipedia, Jury Rigging, https://en.wikipedia.org/wiki/Jury_rigging
[33] Atomic Design Methodology, https://digitalfinancialreporting.blogspot.com/2023/12/atomic-design-methodology.html
[34] Lean Six Sigma, http://www.xbrlsite.com/mastering/Part01_Chapter02.K_LeanSixSigma.pdf

sector, Lean Six Sigma works to produce products and services in a way that meets consumer demand without creating wasted time, money and resources.

Specifically, Lean is 'the purposeful elimination of wasteful activities.' It focuses on making process throughout your company faster, which effects production over a period of time. Six Sigma works to develop a measurable process that is nearly flawless in terms of defects, while improving quality and removing as much variation as possible from the system.

1.14. Evolution of a System

Systems have an evolution[35]. A Wardley map is a tool for understanding a system. As described by the video *Wardley Mapping in 90 Seconds*[36]:

> "A Wardley Map is a sketch. Usually of a business, market, or any other kind of work system. It is a design, maybe a blueprint. It might be right; it might be wrong. But it is something we can discuss and refine together on paper to make sure everything we do in reality is as purposeful as it can be. These designs will inevitably be put to the test by the forces of capitalism. No one is exempt; not even governments or non-profits. So, to help us cope, we acknowledge this fact up front by arranging our blueprint by evolutionary stage; from the uncharted where things are uncertain, high failure, and a gamble; to the industrialized where things are known, reliable, and standard practice. Awareness of these qualities helps us approach each part of the system deliberately. No 'one size fits all', only careful specific intention. But the map is only the beginning. Behind Wardley Mapping is a deeper strategic thinking process. There are many patterns to learn, principles to practice, and moves to make. Take it one step at a time for even the smallest insight can change everything."

Of particular interest are the descriptions provided on that *Stages of Evolution of a Work System*[37] graphic. Consider the contrast between the aspects of the different stages: Genesis, Custom, Product, and Commodity.

Stage of Evolution		I	II	III	IV
x-axis labels (types of capital)	Activity (used)	Genesis	Custom	Product (+rental)	Commodity (+utility)
	Data (implied)	Unmodelled	Divergent	Convergent	Modelled
	Practice (implied	Novel	Emerging	Good	Best
	Knowledge (implied)	Concept	Hypothesis	Theory	Universally Accepted

Aspects of accountancy will move from stage II (custom) to stage III (product) and will ultimately, over time, continue to stage IV (commodity). Much of the tediousness of accounting, reporting, auditing, and analysis will be reduced in the coming years.

1.15. Stakeholders

The objective is for stakeholders that have an interest in a system to agree enough in order to effectively achieve a goal/objective or range of goals/objectives.

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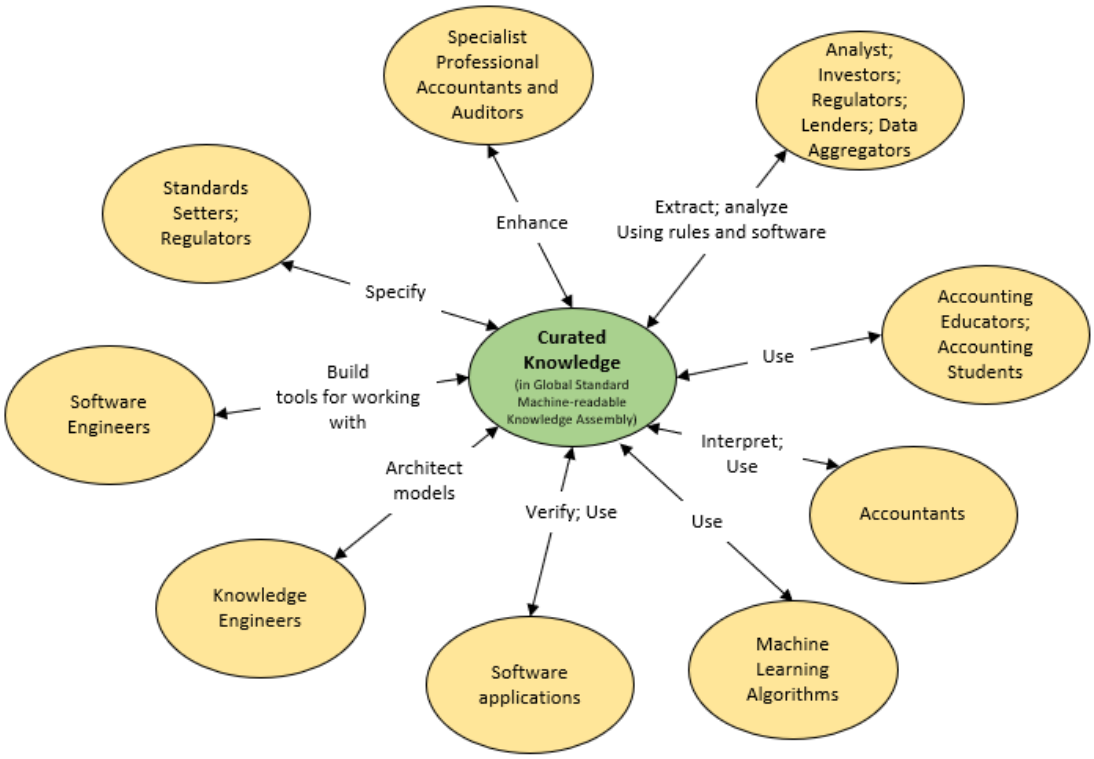
[35] Evolution of a System, http://www.xbrlsite.com/2023/library/EvolutionOfSystem.pdf
[36] YouTube.com, *Wardley Mapping in 90 Seconds*, https://youtu.be/9jvMiq4CZJ0
[37] *Stages of Evolution*, https://learnwardleymapping.com/wp-content/uploads/2021/01/evolution.jpg

Fundamentally, it is the conscious intension of this logical system to safely, reliably, and otherwise successfully communicate information. The stakeholders fundamentally agree to eliminate all possible features that introduce potential failure and to leverage all possible features that lead to provable success.

A logical theory enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.



The objective of the system is the effective exchange of information. Important to the system is the elimination of "wild behavior" by stakeholders.

- **Specify/Describe:** Description of report (specification of what is permitted); created by standards setter or regulator or anyone else specifying a report
  - Machine readable form
  - Machine readable form converted to human readable form
- **Create/Construct:** Construct report based on description (assisted by software utilizing machine readable description)
- **Verify/Review:** Verify that report has been created per description (assisted by software utilizing machine readable description)
- **Extract/Analyze:** Make use of information from report per report description (assisted by software utilizing machine readable description)

1.16. Systematic Computational Analysis

A general purpose financial statement has a formal structure that varies only slightly from industry to industry, country to country, and therefore from reporting economic entity to reporting economic entity. This regularity is by design. The trend is toward even more standardization. Examples of that standardization include International Financial Reporting Standards (IFRS), United States Generally Accepted Accounting Principles (US GAAP), and the Extensible Business Reporting Language (XBRL).

In fact, general purpose financial statements are so formal and predictable as to be literally mechanical.

Over the past 50 years, these general purpose financial statements have grown in size and complexity. And yet, the general mechanism to construct and analyzed has not changed that much for these important artifacts of the global capital markets.

The general purpose financial statement is a designed system; it has been created by humans for a purpose. The global capital markets use the general purpose financial statement as one of many inputs to value an economic entity. Arguably, general purpose financial statements help the global capital markets function better.

Arguably, a better functioning general purpose financial statement would help the global capital markets function even better.

General purpose financial statements were designed for **systematic computational analysis**. General purpose financial statements were designed to be analyzed. Financial statements are knowledge graphs.

General purpose financial statements are comprised of a set of disclosures. Each disclosure is likewise designed for systematic computational analysis. This systematic computational analysis is achieved by leveraging the disclosure design patterns of a disclosure.

The mechanics of this formal, predictable, mechanical nature of a general purpose financial statement can be described using various mechanisms. In the past, that description tended to be paragraphs and sentences of a document. But technologies available today, such as UML models, ontologies, and machine-readable theories expressed using PROLOG are far better suited for describing the mechanics of this very mechanical designed system. Other tools such as logic programming can be used to effectively perform that systematic computational analysis.

Quantitative analysis is an obvious first step toward systematic computational analysis. Qualitative analysis is another step. Strategic analysis is another step. Competitive analysis is another step. Landscape analysis is another step. The Seattle Method pillars of quality is only the beginning of quantitative analysis; it makes sure the information is fundamentally sound.

Models, frameworks, and standards are tools. One needs to be sure they are using the right tools for a job. The tools of "realspace" (think industrial economy) and the tools of "cyperspace" (think information economy) are different. It takes skills and experience to be able to pick the right tools for a job.

Accounting, the universal technology of accountability, is arguably one of the most important technologies invented in the history of human civilization and has been around about 7,000 years. Accounting was invented before writing and before the invention of numbers. The global multinational organization simply could not exist without double entry bookkeeping and accounting.

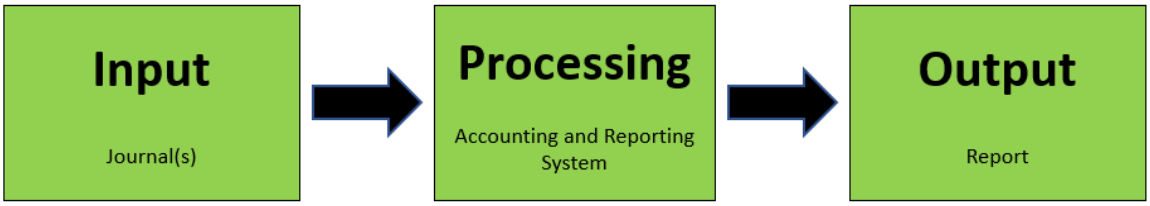
This systematic computational analysis can work across the entire set of stakeholders or supply chain.

2. Essence of Accounting

Essence is described as the core intrinsic nature or indispensable basic quality of something that determines its character.

The purpose of this section is to provide a logical description of the essence of accounting and to demonstrate how accounting, reporting, auditing, and analysis can be performed digitally.

In its simplest form, an accounting and reporting system has three distinct parts: inputs, processing, and outputs. Everything else is details.



Accounting was the world's first communications technology[38]. Of the three most important social technologies; literacy, numeracy, and accounting[39]; accounting was the first to be invented, about 7,000 years ago. Double entry bookkeeping is an industry standard documented in 1494 and contributed to the switch from Roman to Arabic numerals throughout Europe.

Between 5,000 and 10,000 years ago farmers in Mesopotamia, where agriculture was born, used physical objects to count crops and animals[40]. The distinction between types of crops or animals was made by using different types and shapes of objects. Then, in about 3200 BC, around 5,000 years ago, the first spreadsheet was invented.

2.1. Accounting Area of Knowledge

An area of knowledge is a highly organized socially constructed aggregation of shared knowledge for a distinct subject matter. An area of knowledge has a specialized insider vocabulary, underlying assumptions, and persistent open questions that have not necessarily been resolved. Accounting is an area of knowledge.

We will cover important specific details of financial accounting, reporting, auditing, and analysis.

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[38] Jane Gleeson-White, *Double Entry: How the Merchants of Venice Created Modern Finance*, page 10, https://www.amazon.com/Double-Entry-Merchants-Created-Finance/dp/0393346595/

[39] Peter Frampton & Mark Robilliard, *The Joy of Accounting*, https://www.amazon.com/Joy-Accounting-Game-Changing-Approach-Makes/dp/1735312924/

[40] Denise Schmandt-Bessersat, *On the origins of writing*, YouTube.com, https://www.youtube.com/watch?v=kidWY-pJFb0

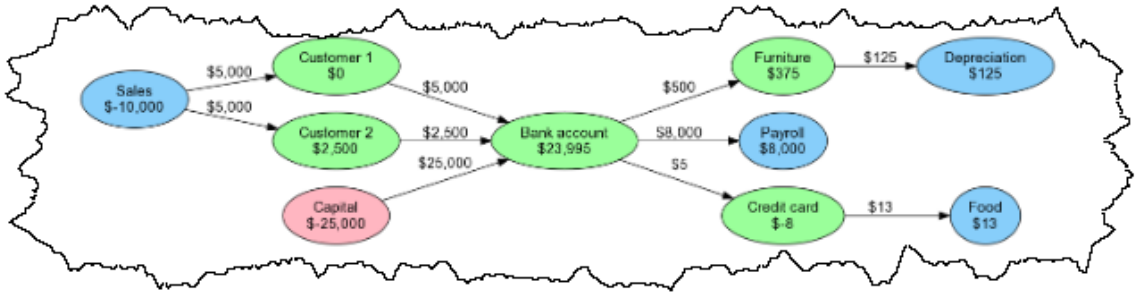
This document strives to explain accounting to non-accountants such as computer scientists. Sometimes accountants are criticized for providing jargon filled explanations. I try and not make that mistake.

While there are people that say that old-school financial reporting processes need to be improved[41] and plenty of very good academic papers that help explain how accounting, reporting, auditing, and analysis in a digital environment might work including *Imagineering Audit 4.0*[42] and *Toward Blockchain-Based Accounting and Assurance*[43]; there is less information on exactly how to make these ideas work in software. This resource hopes to help fill that gap by providing a reliable and repeatable best practices-based method.

2.2. Bookkeeping is Algebra

Mathematics Magazine published an article written by David Ellerman, *The Mathematics of Double Entry Bookkeeping*[44], where Ellerman points out that double entry accounting is based on well-known mathematics construction from undergraduate algebra. But Ellerman laments, "Mathematics and accounting truly seem to live in disjoint universes with no trespassing between them."

This fundamental mathematical nature of double entry accounting offers leverage when creating software. To a computer scientist, accounting is essentially a graph[45]. Accounts are nodes; transactions are edges.



Information from the business events of an economic entity generate transactions, events, circumstances, and other economic phenomenon related to an economic entity's activities which are entered into journals. Financial reports provide information in the form of words and numbers about the status and performance of that economic entity.

One approach to instantiating such an accounting information system is using paper *journal*, having a human *process* the information in the journals, turning the journal

[41] *Changing Old School Financial Report Creation Processes*, http://xbrl.squarespace.com/journal/2017/2/14/changing-old-school-financial-report-creation-processes.html
[42] Jun Dai and Miklos Vasarhelyi, Rutgers University, *Imagineering Audit 4.0*, http://aaajournals.org/doi/abs/10.2308/jeta-10494?code=aaan-site
[43] Jun Dai and Miklos Vasarhelyi, Rutgers University, *Toward Blockchain-Based Accounting and Assurance*, http://aaajournals.org/doi/10.2308/isys-51804
[44] David P. Ellerman, *The Mathematics of Double Entry Bookkeeping*, http://www.ellerman.org/wp-content/uploads/2012/12/DEB-Math-Mag.CV .pdf
[45] Martin Kleppmann, *Accounting for Computer Scientists*, http://martin.kleppmann.com/2011/03/07/accounting-for-computer-scientists.html

entries into a *report*. An example of such a system is this 19th century German ledger[46]:

Another approach is to instantiating such an accounting information system is using a computer readable journal, have a computer software application process the journals, turning the machine-readable journal entries into a report. An example of such a system is hledger[47]:

```
; $HOME/.hledger.journal (or $LEDGER_FILE)

2020-01-01 opening balances
    assets:checking         $1234
    equity

2020-03-15 client payment
    assets:checking         $2000
    income:consulting

2020-03-20 Sprouts
    expenses:food:groceries  $100
    assets:cash               $40
    assets:checking
```

```
$ hledger bs
Balance Sheet 2020-03-20

             || 2020-03-20
=============++=============
 Assets      ||
-------------++-------------
 assets      ||      $3134
   cash      ||        $40
   checking  ||      $3094
-------------++-------------
             ||      $3134
=============++=============
 Liabilities ||
-------------++-------------
-------------++-------------
             ||
=============++=============
 Net:        ||      $3134

$ hledger is -M
Income Statement 2020-01-01-2020-03-20

                          || Jan  Feb    Mar
==========================++=================
 Revenues                 ||
--------------------------++-----------------
 income:consulting        ||   0    0  $2000
--------------------------++-----------------
                          ||   0    0  $2000
==========================++=================
 Expenses                 ||
--------------------------++-----------------
 expenses:food:groceries  ||   0    0   $100
--------------------------++-----------------
                          ||   0    0   $100
==========================++=================
 Net:                     ||   0    0  $1900
```

[46] Wikipedia, *Accounting Information System*, https://en.wikipedia.org/wiki/Accounting_information_system
[47] hledger.org, hledger, https://hledger.org/

hledger is a port/branch of another similar computer software application called Ledger[48]. Both hledger and Ledger are part of the plain text accounting movement[49].

I will use hledger and Ledger to help explain the essence of accounting. Several weeks ago, I created an accounting process automation and record to report demonstration[50]. That demonstration was explained in this video, Seeing XBRL Work[51]. In that demonstration, I showed a set of accounting transactions going from the input process (journal) to the output process (report). The processing was achieved using a Microsoft Access Database application that I created and several XBRL tools to verify the XBRL technical syntax and the accounting and reporting logic of the report.

To that prior demonstration I am adding an accounting system to verify that the information in the journal is correct as contrast to me manually verifying the journal entries. Further, I am going to explain complexities and show how those complexities fit into this basic accounting system.

2.3. Difference Between Bookkeeping and Accounting

People often use the terms "bookkeeping" and "accounting" interchangeably[52]. But bookkeeping and accounting are two different things. Here are definitions of both:

- **Bookkeeping** is a mechanical process of recording transactions. Bookkeeping is an action; it is a record keeping process.
- **Accounting** is about determining what constitutes the transactions that are then recorded per the bookkeeping process. Accounting is the language used by bookkeeping. Accounting is a communications tool. Accounting is a classification system used for organizing recorded transactions.

Bookkeeping history is explained in the book *Double Entry: How the Merchants of Venice Created Modern Finance*[53] by Jane Gleeson-White. A search on "difference between bookkeeping and accounting" will provide you on additional details.

Basically, bookkeeping relates to transactions, journals, ledgers, trial balances, chart of accounts and the mechanical process and details involved with recording transactions. Accounting relates to coming up with a proper chart of accounts, classifying transactions, converting the trial balance into a set of financial statements and getting the accounting details right.

2.4. Spreadsheets

Those farmers in Mesopotamia began documenting information using clay tablets in the earliest form of human writing ever discovered called Cuneiform. They

[48] Ledger, https://www.ledger-cli.org/index.html
[49] Charles Hoffman, CPA, Plain Text Accounting, http://xbrl.squarespace.com/journal/2020/5/5/plain-text-accounting.html
[50] Accounting Process Automation, http://xbrlsite.azurewebsites.net/2020/master/automation/index.html
[51] YouTube.com, Seeing XBRL Work, https://youtu.be/xWOvwUyMZ28
[52] Accounting Basics (Brainstorming), http://xbrlsite.azurewebsites.net/2021/library/AccountingBasics.pdf
[53] Amazon.com, Jane Gleeson-White, *Double Entry: How the Merchants of Venice Created Modern Finance*, https://www.amazon.com/gp/product/B007Q6XKA8/

partitioned their clay tablet into rows, columns, and cells. These farmers used single-entry accounting. The spreadsheet below documents an account of barley distribution[54]:

Spreadsheets have evolved since then and they are very likely to continue to evolve to serve the needs of accountants[55].

2.5. Invention and Documentation of Double-entry System

In 1211 AD a bank in Florence was the first documented use of double-entry accounting[56]. Around 1300 AD double-entry accounting came of age. In 1494 AD during the Renaissance, Venetian mathematician and Franciscan friar Luca Pacioli[57] published a book, *Summa de arithmetica, geometria. Proportioni et proportionalita* (Sum of Arithmetic, Geometry, Proportion and Proportionality)[58].

That book documented an approach to accounting now called double-entry bookkeeping[59] and recommended that others use this approach. The approach

[54] Metropolitan Museum, Proto-Cuneiform tablet with seal impressions: administrative account of barley distribution with cylinder seal impression of a male figure, hunting dogs, and boars, https://www.metmuseum.org/art/collection/search/329081

[55] *Special Purpose Logical Spreadsheet for Accountants*, http://www.xbrlsite.com/2023/Library/SpecialPurposeLogicalSpreadsheetsForAccountants.pdf

[56] Geoffrky Alan Lee, *The Development of Italian Bookkeeping 1211–1300*, Wiley, https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-6281.1973.tb00183.x

[57] Wikipedia, Luca Pacioli, https://en.wikipedia.org/wiki/Luca_Pacioli

[58] Wikipedia, Summa de arithmetica, https://en.wikipedia.org/wiki/Summa_de_arithmetica

[59] Ancient double-entry bookkeeping. Lucas Pacioli's treatise (A. D. 1494--the earliest known writer on bookkeeping) reproduced and translated with reproductions, notes and abstracts

allowed for better error detection and the ability to differentiate unintended errors from fraud. Accountants adopted that new approach.

Another book documenting double-entry accounting was *Della mercatura e del mercante perfetto*[60] (translated *Of commerce and the perfect merchant*) which was written by Benedetto Cotrugli in 1458 but it was not published until 1573. (a.k.a. Benedikt Kotruljevic, a.k.a. Benedetto Cotrugli Raguseo)[61]

2.6. Double-entry Bookkeeping Model

At the foundation of every financial reporting scheme is the double-entry bookkeeping model[62]. Simply stated, that model is: **DEBITS = CREDITS**. The double-entry bookkeeping model is a mathematical model. (If you don't understand this double-entry bookkeeping, this video is helpful[63]!)

Single-entry bookkeeping[64] is how 'everyone' would do accounting. In fact, that is how accounting was done before double-entry bookkeeping was invented. Single-entry bookkeeping simply uses one list to record information about transactions.

Double-entry bookkeeping in essence uses two lists of information and the two lists are compared/synchronized to one another and the two lists must agree.

Double-entry bookkeeping[65] adds an additional important property to an accounting system, that of a clear strategy to identify errors and to remove the errors from the system.

Even better, it has a side effect of clearly firewalling errors as either accident or fraud[66]. This then leads to the ability to specify an audit strategy.

Double-entry bookkeeping is how professional accountants do accounting.

And so, double-entry bookkeeping was the invention of medieval merchants and was first documented by the Italian mathematician and Franciscan Friar Luca Pacioli[67]. The Venetian Method of double entry bookkeeping is the best practice used by most professional accountants today[68].

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from Manzoni, Pietra, Mainardi, Ympyn, Stevin and Dafforne,
https://archive.org/details/ancientdoubleent00geij/page/n3/mode/2up

[60] Wikipedia, *Della mercatura e del mercante perfetto*,
https://en.wikipedia.org/wiki/Della_mercatura_e_del_mercante_perfetto

[61] Croatian World Network, *Croation Inventions*,
https://www.croatia.org/crown/articles/6268/1/E-CROATIAN-INVENTIONS.html

[62] David P. Ellerman, *The Mathematics of Double Entry Bookkeeping*,
http://www.ellerman.org/wp-content/uploads/2012/12/DEB-Math-Mag.CV_.pdf

[63] YouTube, *2016 Debit Credit Theory Accounting Rap Song from O'Neill High School*,
https://www.youtube.com/watch?v=PHanSCcMb_I

[64] Wikipedia, *Single-entry Bookkeeping System*, retrieved August 30, 2016,
https://en.wikipedia.org/wiki/Single-entry_bookkeeping_system

[65] Wikipedia, *Double-entry Bookkeeping System*, retrieved August 30, 2016,
https://en.wikipedia.org/wiki/Double-entry_bookkeeping_system

[66] *Fool Me Once*, https://digitalfinancialreporting.blogspot.com/2023/07/fool-me-once.html

[67] Wikipedia, *Luca Pacioli*, retrieved August 30, 2016,
https://en.wikipedia.org/wiki/Luca_Pacioli

[68] *Accounting: Our First Communications Technology*,
http://xbrl.squarespace.com/journal/2021/10/23/accounting-our-first-communications-technology.html

Double-entry bookkeeping is perhaps one of the greatest discoveries and its impact on commerce and its significance is difficult to overstate. Which came first, double-entry bookkeeping or the enterprise[69]? Was it double-entry bookkeeping and what it offered that enable the large enterprise to exist; or, did the large enterprise create the need for double-entry bookkeeping?

Triple-entry accounting[70] further builds on double-entry in that triple-entry links a transaction in two double-entry ledgers and the link is publicly available for all to see certain specific aspects of a transaction. You are still able to explain the reasoning behind the entry but additionally the transaction is visible for all to see which makes it very tough to lie since others are watching. It would be illogical for the transaction to not be reflected the same in both ledgers.

2.7. Foundational Mathematical Equation for Double-Entry Accounting

The foundational basis of double-entry accounting is straightforward. Quoting David Ellerman from his paper *The Math of Double-Entry Bookkeeping: Part I (scalars)*[71]:

"Given an equation w + … + x = y + … + z, it is not possible to change just one term in the equation and have it still hold. Two or more terms must be changed."

And so, the left-hand side of the equation "w + … + x" (the DEBIT side) must always equal the right-hand side of the equation "y + … + z" (the CREDIT side) in double-entry accounting.

The reason that double-entry accounting is used, as contrast to single-entry accounting, is double-entry accounting's capability to detect errors and to distinguish an error from fraud.

Of course, there are a lot of details associated with setting up and operating an accounting system appropriately, but the fundamental feature is that DEBITS must equal CREDITS and if they don't, then something is up which needs to be investigated and corrected.

2.8. Universal Technology of Accountability

Double entry bookkeeping is a universal technology used around the world by organizations, individuals, and communities. Regardless of the size of the organization, the location in the world, the activity of the organization, or the complexity of the organization; the double entry bookkeeping model works. Double entry bookkeeping will never become obsolete. Formally documented by Luca Pacioli in 1494 and referred to as the Venetian Method, double entry bookkeeping is a global standard.

Accounting using the double entry bookkeeping method is about documentation and accountability using a proven, professional approach that detects errors and differentiates an unintentional error from an intentional error (i.e. fraud). Without accountability civilization cannot advance. Accountability advances civilization,

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[69] Ian Grigg, *Triple Entry Accounting, A Very Brief History of Accounting, Which Came First - Double Entry or the Enterprise?,* http://iang.org/papers/triple_entry.html
[70] *Triple-Entry Accounting*, https://youtu.be/wWXy7wUDEoQ?si=3U9gKn9fl7AYxXsj
[71] David Ellerman, *The Math of Double-Entry Bookkeeping: Part I (scalars)*, http://www.ellerman.org/the-math-of-double-entry-bookkeeping-part-i-scalars/

economics, enterprises, environmental stewardship, personal property, governmental stewardship, etc.

Accounting is one of the most important technologies invented in the history of human civilization and has been around about 7,000 years. Accounting was invented before writing and before the invention of numbers. The global multinational organization simply could not exist without double entry bookkeeping and accounting.

The simple concepts that are used to build financial accounting and financial reporting yield an elegant result.

Orthodox is defined as conforming to what is generally or traditionally accepted as right or true; established and approved. Topology is the way in which constituent parts are logically interrelated or arranged. Orthodox topologies or logical schemas of financial reports that summarize some set of accounting transactions that result from some set of business events of an economic entity can be differentiated from the unorthodox given a clear and complete set of rules.

This universal technology for accountability[72] is grounded, even ingrained, in medieval traditions. Yet this universal technology for accountability is going to be impacted by structured information, artificial intelligence, digital distributed ledgers, and other such technologies. And they should be. Those same technologies that are causing the ever-increasing volume and complexity of information that is overwhelming us is also the solution to the information overload that is being experienced

2.9. Accounting Equation

Building on the double-entry bookkeeping model is the accounting equation[73]. Assets (a debit) is always equal to the sum of Liabilities (a credit) plus Equity (a credit). This is essentially a second layer building on the first layer. The foundational semantics of double-entry accounting is the accounting equation:

"Assets = Liabilities and Equity"

The terms "assets", "liabilities", and "equity" have very specific and generally well understood meanings in accounting and business. Accounting is referred to as "the language of business". This high-level accounting equation is broken down into two trees of information. Those two trees are the detailed items which make up a financial report, "Assets" and "Liabilities and Equity". The semantics reiterates what that foundational equation states and assigns meaning to the numbers that make up those DEBITS and CREDITS.

Empirical evidence gathered shows that there are a finite number of ways used to organize the high-level concepts that make up the three primary financial statements: balance sheet, income statement, cash flow statement. I call these different organizations reporting styles[74].

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[72] *Universal Technology for Accountability*, https://digitalfinancialreporting.blogspot.com/2023/02/universal-technology-for-accountability.html

[73] Wikipedia, *Accounting Equation*, https://en.wikipedia.org/wiki/Accounting_equation

[74] Charles Hoffman, *Making the Case for Reporting Styles*, http://xbrlsite.azurewebsites.net/2017/library/MakingTheCaseForReportingStyles.pdf

2.10. Financial Reporting Schemes

As explained by the FASB in SFAC 6[75], "Elements of financial statements are the building blocks with which financial statements are constructed—the classes of items that financial statements comprise. The items in financial statements represent in words and numbers certain entity resources, claims to those resources, and the effects of transactions and other events and circumstances that result in changes in those resources and claims."

Financial standards setters or perhaps regulators create reporting schemes. Every financial reporting scheme fundamentally adheres to the accounting equation in some form. Creators of financial reporting schemes tend to create a set of high-level financial concepts that map directly to assets, liabilities, and equity and the rule "assets = liabilities + equity".

Here is a comparison of the core set of interrelated elements defined by five different financial reporting schemes[76].

Reporting Scheme	US GAAP issued by FASB	IFRS issued by IASB	FRF for SMEs issued by AICPA	IPSAS issued by IPSASB	GAS issued by GASB
Assets	Assets	Assets	Assets	Assets; Other Resources	Assets and Deferred Inflow of Resources
Liabilities	Liabilities	Liabilities	Liabilities	Liabilities; Other Obligations	Liabilities and Deferred Outflow of Resources
Equity or Net Assets	Equity (or Net Assets)	Equity (or Net Assets)	Equity (or Net Assets)	Net Financial Position	Net Position
Comprehensive Income	Comprehensive Income	Income and Expenses	Net income	Surplus or Deficit	Change in Net Position
Investments by Owners	Investments by Owners	Contributions from Holders of Equity Claims	Investments by Owners	Ownership Contributions	Increase in Net Position (Implied)
Distributions to Owners	Distributions to Owners	Distributions to Holders of Equity Claims	Distributions to Owners	Ownership Distributions	Decrease in Net Position (Implied)
Revenues	Revenues	Income	Revenues	Revenues	Inflow of Resources
Expenses	Expenses	Expenses	Expenses	Expenses	Outflow of Resources
Gains	Gains		Gains		
Losses	Losses		Losses		

On the one hand, the unique aspects of an economic entity need to be articulated. On the other hand, investors and financial analysts need to be able to compare the financial position and financial performance of different economic entities. Standard financial reporting schemes strive to strike an appropriate balance.

2.11. Interrelated Elements of Financial Statements

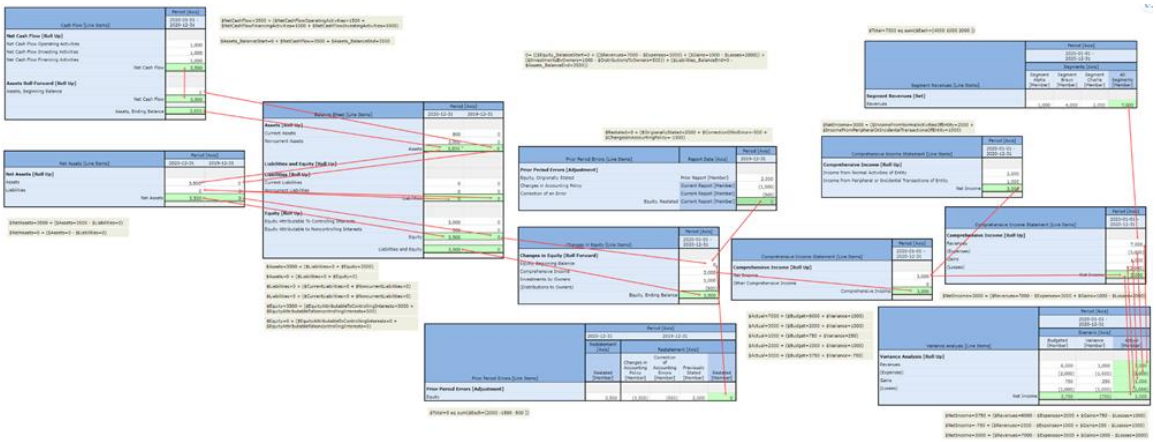
Every financial reporting scheme defines a core set of interrelated elements of a financial statement that are fundamentally grounded in some form of the accounting equation. For example, the Financial Accounting Standards Board (FASB) defines these ten interrelated elements of a financial statement in SFAC 6[77]; Assets, Liabilities, Equity, Comprehensive Income, Investments by Owners, Distributions to Owners, Revenues, Expenses, Gains, Losses. Then, additional elements are defined

[75] FASB, SFAC 6, Elements of Financial Statements, page 14, https://www.fasb.org/pdf/con6.pdf
[76] Charles Hoffman, CPA, *Comparison of Elements of Financial Statements*, http://xbrlsite.azurewebsites.net/2019/core/ElementsOfFinancialStatements.pdf
[77] FASB, SFAC 6, Elements of Financial Statements, page 23.

based on that core set. As is explained next, the interrelations of these elements are intentional.

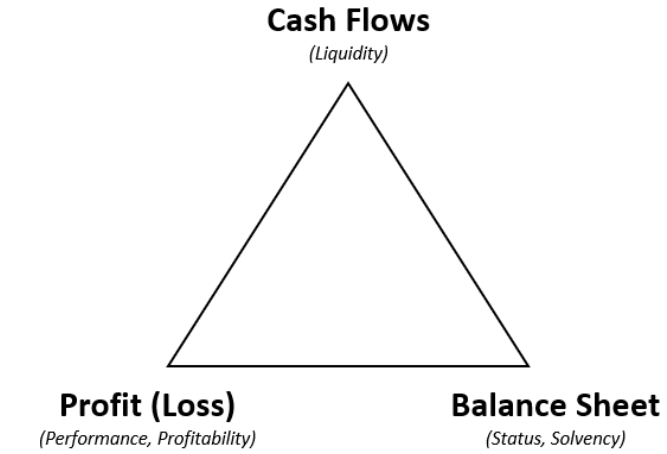
2.12. Articulation

Articulation[78] is the conscious interconnection of the primary financial statements mathematically. This screen shot below depicts this interconnection[79]:



2.13. Interconnected Stocks and Flows

Articulation is the notion that the elements of a financial statement are intentionally interrelated into stocks and flows that explain the status, performance, and liquidity of an economic entity. The following graphic[80] helps one understand these interconnections:



Stocks are instances of information at a specific point in time. Flows are durations of information between two points in time. Flows change the stocks.

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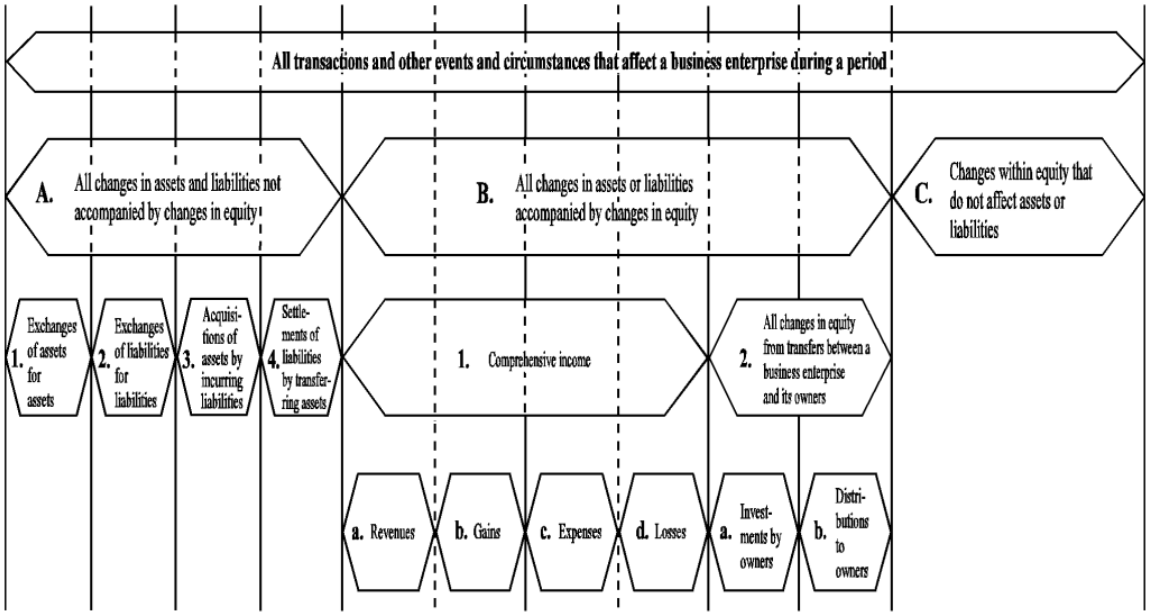
[78] Articulation, https://digitalfinancialreporting.blogspot.com/2023/08/understanding-articulation.html
[79] PROOF Articulation, https://www.xbrlsite.com/seattlemethod/platinum/proof/PROOF_Articulation.jpg
[80] Inspired by a similar graphic provided by Dr. Willi Brammertz, http://www.brammertz-consulting.ch/about/about-willi-brammertz/

A balance sheet provides a set of "stocks" that provide information about the status of an economic entity. An income statement provides a set of "flows" that provide information about the performance of that economic entity in terms of profit (loss). A cash flow statement provides a set of "flows" that provide information about the liquidity of that economic entity in terms of cash flows.

The interconnections will be made more tangible in a moment when we discuss the four statement model.

2.14. Transactions, Events, Circumstances, Other Phenomenon

The FASB in SFAC 6 (section 64, page 41)[81] points out that all transactions, events, circumstances, and other phenomenon that impact an economic entity can be grouped:



These changes can be grouped into eight primary bookkeeping or accounting entries categories:

1. Exchange of assets.
2. Exchange of liabilities.
3. Exchange asset for liability
4. Exchange liability for asset.
5. Exchange asset for income.
6. Exchange liability for expense. (special case of reserve building)
7. Moving profit (loss) into equity.
8. Moving asset or liability to equity.

While it is possible to have other combinations, those combinations are rare and potentially suspect.

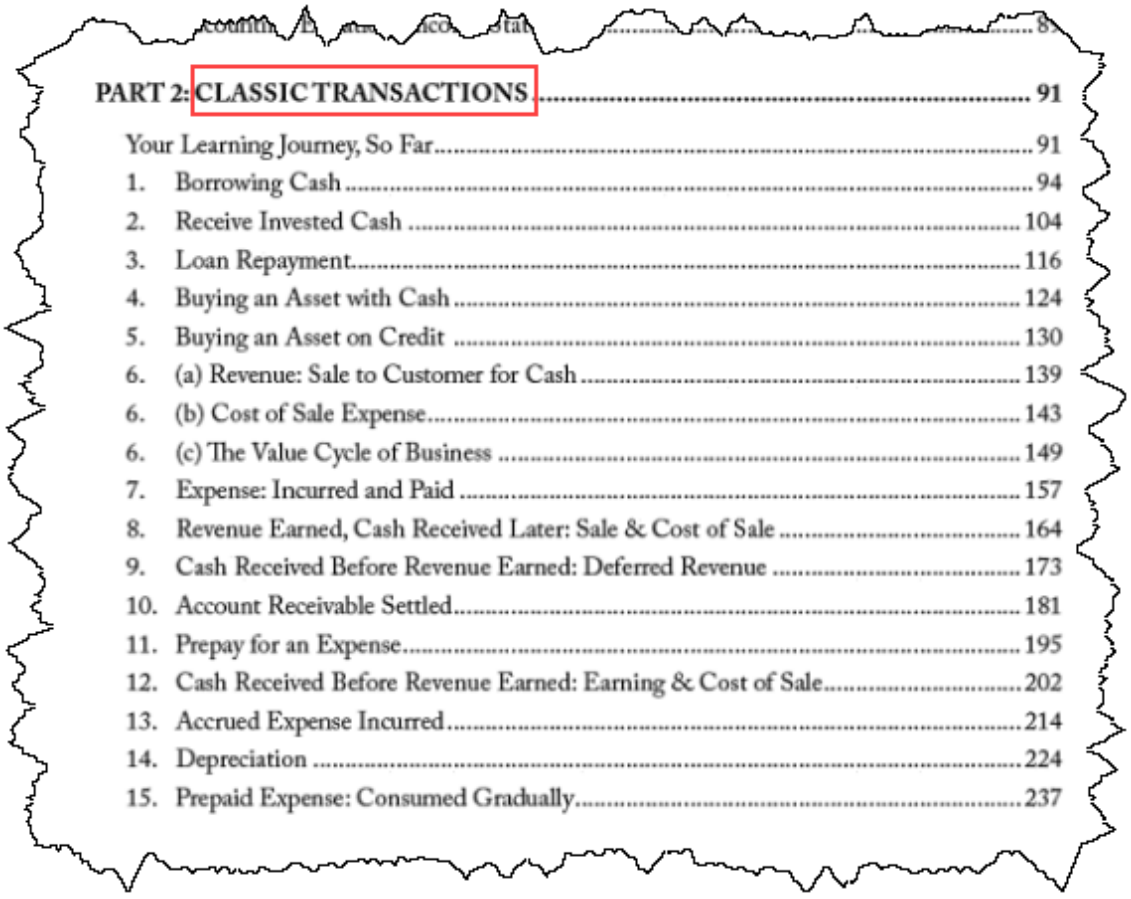
[81] FASB, SFAC 6, Elements of Financial Statements, section 64, page 41.

2.15. Business Events

While transactions are what are entered into an accounting system by bookkeepers and described using the language of accounting; those transactions represent business events that have occurred for an economic entity. More on this later.

2.16. Classic Business Events

The roll forward of real accounts described in the last section help you recognize that there are patterns of transactions[82] and the business events that drive those transactions. The Joy of Accounting provides a list of these transaction patterns which they refer to as classic transactions[83]:



In reality though, it is better to see that the patterns are in the nature of the business events[84] for which transactions are posted into an accounting system.

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[82] Classic Transactions and Canonical Representations of Business Events, https://digitalfinancialreporting.blogspot.com/2023/01/classic-transactions-and-canonical.html

[83] Peter Frampton & Mark Robilliard, *The Joy of Accounting*, https://www.amazon.com/Joy-Accounting-Game-Changing-Approach-Makes/dp/1735312924/

[84] *Business Events Drive Transactions*, http://xbrl.squarespace.com/journal/2022/1/12/business-events-drive-accounting.html

Another approach to seeing the patterns of transactions is in the economic events described by the Resource-Event-Agent (REA) conceptual model[85].

2.17. Obstacles to Automation

Continuous accounting, continuous reporting, artificial intelligence assisted audits, algorithmic regulation, computational professional services, automated analysis all offer unprecedented opportunities to modernize accounting processes. But there are fundamental challenges to automating accounting and reporting processes. Here are fundamental obstacles that need to be overcome:

- **Information is entered into systems after transaction entry**: The reality of many if not most finance processes is that a significant amount of information is managed using spreadsheets and that is where context tagging and classification occur. *The fix?* Enter context tagging and classification information sooner, preferably at time of transaction entry.
- **Complex disparate systems trap information**: The reality of many if not most finance processes is many dissimilar systems making information integration complex. Often, complexity is self-inflicted such as an incorrectly set up chart of accounts or a less than adequate mapping between the chart of accounts and a report writer or audit lead schedules. *The fix?* Take the time to set up your accounting systems correctly.
- **Missing metadata**: Far too often information necessary to flow data through a system is entered into the system at the end of a process instead of at the beginning of a process. This missing metadata makes it impossible to automate processes. *The fix?* Establish standard metadata, enter that metadata as early in the process as possible, enable information to flow through the process where possible.
- **Missing information**: Commonly, information necessary for a system to be automated is not available to the system and therefore information is supplemented by manually created spreadsheets. *The fix?* Bring more and more tasks and processes into core systems and where possible avoid supplementing information using spreadsheets.
- **Overly manual process control mechanisms**: Process control mechanisms today tend to be overworked accounting professionals that have to manually control process output quality within systems that push far too much work to the end of the process. This manual approach is expensive, not reliable enough letting errors slip through the systems, and cause more important work to be delayed or simply left undone. *The fix?* Human-machine collaboration. Augment manual processes with automated processes and let machines help overworked humans get work done. Leverage Lean Six Sigma[86] philosophies and techniques.
- **Communications issues**: The typical professional accountant does not really grasp the possibilities that technology offers to improve processes

[85] Understanding the Resource-Event-Agent (REA) Conceptual Model, http://xbrl.squarespace.com/journal/2016/9/27/understanding-the-resource-event-agent-rea-conceptual-model.html
[86] Lean Six Sigma, http://www.xbrlsite.com/mastering/Part01_Chapter02.K_LeanSixSigma.pdf

accurately. Computer scientists do not tend to understand important nuances of accounting, reporting, auditing, and analysis and therefore cannot build systems precisely or set priorities effectively. Most accountants focus on getting work done allocating little to no effort towards process improvement. *The fix?* It will take far less time for a professional accountant to learn what is necessary to communicate effectively with computer scientists than it would for a computer scientist to understand the important subtleties and nuances of accounting, reporting, auditing, and analysis. Take the time to improve your skills. If you don't want to make the investment, then hire a good consultant that has.

A properly set up chart of accounts, accounts properly assigned account "types", use of roll forward grouping codes, a properly set up report writer, and entering information into accounting systems rather than spreadsheets can enable the possibility of automation. Properly setting up an accounting system will enable significant changes in accounting processes to occur[87].

2.18. Objective of Financial Reporting

The following problem description or business use case was inspired by a similar sort of description by Harry S. Delugach, Associate Professor of Computer Science, in a presentation, *Common Logic Standards Development*, (page 7). Fundamentally, a financial statement serves this purpose:

> Two economic entities, A and B, each have information about their financial position, financial performance, and liquidity. They must communicate their information to an investor who is making investment decisions which will make use of the combined information so as to draw some conclusions. All three parties (economic entity A, economic entity B, investor) are using a common set of basic logical principles (facts, statements, deductive reasoning, etc.), common financial reporting standard terms and associations between terms (terms, associations, structures, assertions for a reporting scheme US GAAP, IFRS, IPSAS, etc.), and a common world view so they should be able to communicate this information fully, so that any inferences which, say, the investor draws from economic entity A's information should also be derivable by economic entity A itself using common basic logical principles, common financial reporting standards (terms, associations, structures, rules), and common world view; and vice versa; and similarly for the investor and economic entity B.

This problem/use case has been effectively solved for hundreds of years via the use of paper-based and human readable general-purpose financial statements.

Financial reports can be interrogated systematically and logically.

2.19. Things that can Go Wrong

Do the bookkeeping transactions and the accounting used to create a financial report reflect a "true and fair" story and provide accurate information about the financial

[87] *Turning Accounting On its Ear (Brainstorming*), https://digitalfinancialreporting.blogspot.com/2023/02/turning-accounting-on-its-ear.html

position, financial performance, and liquidity of an economic entity? What exactly can go wrong?

There are many different things that can go wrong including measurement or valuation issues, timing issues, and such. But things that can go wrong can be grouped into the following categories:

- **Unintended errors** (a.k.a. an unintended mistake)
  - Simple errors
  - Complex errors (a.k.a. multiple simple errors)
- **Intended criminal errors** (a.k.a. fraud)
- **Judgment errors** (a.k.a. applying accounting rules inappropriately or in ways that are not permitted)

Things that have gone wrong could be detected by internal review processes or by independent third-party review or audit processes.

2.20. Financial Reports are Not Forms

General purpose financial statements are essentially "complex messages with variability". As explained by the FASB in SFAC 6, variability is an intentional, inherent characteristic of a financial statement. For example, per SFAC 6, page 47, paragraph 77[88]:

"Examples of intermediate components in business enterprises are gross margin, income from continuing operations before taxes, income from continuing operations, and operating income. Those intermediate components are, in effect, subtotals of comprehensive income and often of one another in the sense that they can be combined with each other or with the basic components to obtain other intermediate measures of comprehensive income."

That statement describes the "intermediate components" that contribute to the variability of a financial report.

A financial report is essentially a graph as defined by graph theory[89]. A graph is a mathematical structure used to model pairwise relations between objects. Graphs don't really exist in the real world, but they are used to describe real world objects to things like computer software.

It would be appropriate to call a financial report a "knowledge graph" and an XBRL-based financial statement is a machine-readable knowledge graph[90]. Financial report knowledge graphs can be interrogated systematically and logically using machine-based processes.

A "tree" is a special type of graph. So, for simplicity's sake let's use the term "tree". And so, imagine a financial report as a "tree" of information. Here is a tree:

---

[88] Ibid.
[89] Wikipedia, *Network Theory*, https://en.wikipedia.org/wiki/Network_theory
[90] *Financial Report Knowledge Graphs*, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf

And here is a "forest" of financial reports (i.e. a set of trees, for example the SEC EDGAR system might be considered a "forest" of financial reports:

But really, the forest above is not a good representation of US GAAP or IFRS forest of financial reports. The forest above assumes that all the "trees" are the same, which they are not because of the inherent variability of a financial report, the different intermediate subtotals as previously described. And so, a "forest" of US GAAP or IFRS financial reports might better be represented by something more like this:

Due to the inherent variability of financial reports, they are not all the same. Yes, financial reports have similarities and they have patterns. But financial reports are not, and should not, be forms like the first forest.

But you can find patterns in the forest that is full of trees, the trees can be put into "sets" that have similarities. For example, those sets of financial reports when organized might look something like this:

One might be tempted to call the forest seven different types of "forms" because unlike the one pattern in the first forest, we have seven patterns and therefore seven different types of forms. But this would not be accurate.

2.21. Intermediate Components

To understand the notion of intermediate components, consider the income statement. SFAC 6 clearly defines the components of comprehensive income to be[91]:

- Revenues
- Gains
- Expenses
- Losses

Those four components total to comprehensive income.

Further, if you read the definitions of the four components of comprehensive income the definitions of those four terms refer to the notions of "normal activities" and "peripheral activities"

- Income from Normal Activities of Entity

[91] ibid, page 42, paragraph 65 B 1.

- Income from Peripheral or Incidental Transactions of Entity

Those two components likewise total to comprehensive income.

Reading the definitions of those four components of comprehensive income again, it is clear that "Revenues" and "Expenses" might not necessarily total to the component "Income from Normal Activities of Entity"; nor is it the case that "Gains" and "Losses" would total to "Income from Peripheral or Incidental Transactions of Entity".

It is likewise true that the typical financial report never reports their income statement using either of the above to breakdowns of comprehensive income. Income statement line items tend to be along the lines of the following components:

- Revenues (meaning revenues from normal activities or "operating" revenues)
- Cost of Revenues (meaning direct operating expenses)
- Gross Profit (Loss) (an intermediate subtotal)
- Operating expenses (meaning indirect operating expenses if the line item Cost of Revenues is reported)
- Other Operating Income (meaning operating gains that don't belong in the line item Revenues)
- Operating Income (Loss) (meaning the portion of comprehensive income relating to normal activities of the entity)
- Nonoperating Expenses (Income) (meaning peripheral or incidental expenses, gains, or losses)
- Income from Continuing Operations Before Taxes (an intermediate subtotal)
- Income Tax Expense (Benefit) (meaning taxes or benefits from normal or peripheral activities)
- Income from Continuing Operations After Taxes (an intermediate subtotal)
- Income (Loss) from Discontinued Operations (meaning a portion of income from normal activities that, however, have been discontinued)
- Net Income (Loss) (an intermediate subtotal)
- Net Income (Loss) Attributable to Parent (the portion of net income attributable to controlling interests)
- Net Income (Loss) Attributable to Noncontrolling Interests (the portion of net income attributable to noncontrolling interests)
- Other Comprehensive Income (meaning components that are specifically defined to be part of comprehensive income other than all other previous components)
- Comprehensive Income (defined by SFAC 6)

Now, this is only a portion of the intermediate components and subtotals that might exist on the income statements of most industries that take into considerations important ideas of "direct" versus "indirect" expenses; "operating" and "nonoperating"; "continuing" and "discontinued" operations; and other such important distinctions. Other industries such as banking have completely different line items and subtotals that might be used.

Professional accountants understand these important distinctions and explaining the specifics of these distinctions are beyond the scope of this document. Further, there are nuances and subtleties that need to be considered when determining what line items and subtotals should be reported. These line items and subtotals are based, in part, on professional judgement and even personal preference sometimes but always need to be justifiable. Further, the logic of the specific line items and subtotals is both knowable and should make accounting sense.

2.22. Variability of Intermediate Components

Every financial report has inherent variability that is the result of explicitly allowing intermediate components of a financial report (i.e. subtotals) to be combined in appropriate but perhaps different ways depending on the needs of the reporting economic entity. Again, this is explained by the FASB in detail within SFAC 6[92].

There are a multitude of other patterns within financial reports that can be leveraged. For example, some financial reporting schemes require that each of the four primary financial statements be present within a set of financial statements in some form: balance sheet, income statement, statement of changes in equity, statement of cash flows. Disclosure notes such as the basis of reporting and nature of the economic entity providing the financial report. These additional patterns which tend to be unique per financial reporting scheme are beyond the scope of this basic explanation of the logical conceptualization of a financial report.

A financial **reporting scheme**[93] is a formal specification for how financial reports are to be created and the underlying accounting rules and is usually created by a standards setter or regulator. For example, US GAAP, IFRS, and IPSAS are all financial reporting schemes. Financial reports are not forms. Financial reporting schemes allow for a certain amount of flexibility and variability when reporting certain specific disclosures or subtotals contained within a disclosure.

2.23. Comparability Including Consistency

Per SFAS 8[94] issued by the FASB, page 19, QC23:

"Comparability is not uniformity. For information to be comparable, like things must look alike and different things must look different. Comparability of financial information is not enhanced by making unlike things look alike any more than it is enhanced by making like things look different."

A form is uniformity. As stated, financial statements are not forms. And while financial statements are not forms, they are likewise not random either.

It is important to understand what the FASB means by "comparability (including consistency)". That is explained in SFAS 8[95]. Here is the pertinent section of that document. This is well stated, very clear, and every word is worth reading:

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[92] ibid, page 47, paragraph 77.

[93] Reporting Scheme, http://xbrlsite.azurewebsites.net/2018/Library/ReportingSchemes-2018-12-30.pdf

[94] FASB, *Statement of Financial Accounting Concepts No. 8*, page 19, http://www.fasb.org/cs/BlobServer?blobcol=urldata&blobtable=MungoBlobs&blobkey=id&blobwhere=1175822892635&blobheader=application/pdf

- **QC20**. Users' decisions involve choosing between alternatives, for example, selling or holding an investment, or investing in one reporting entity or another. Consequently, information about a reporting entity is more useful if it can be compared with similar information about other entities and with similar information about the same entity for another period or another date.
- **QC21**. Comparability is the qualitative characteristic that enables users to identify and understand similarities in, and differences among, items. Unlike the other qualitative characteristics, comparability does not relate to a single item. A comparison requires at least two items.
- **QC22**. Consistency, although related to comparability, is not the same. Consistency refers to the use of the same methods for the same items, either from period to period within a reporting entity or in a single period across entities. Comparability is the goal; consistency helps to achieve that goal.
- **QC23**. Comparability is not uniformity. For information to be comparable, like things must look alike and different things must look different. Comparability of financial information is not enhanced by making unlike things look alike any more than it is enhanced by making like things look different.
- **QC24**. Some degree of comparability is likely to be attained by satisfying the fundamental qualitative characteristics. A faithful representation of a relevant economic phenomenon should naturally possess some degree of comparability with a faithful representation of a similar relevant economic phenomenon by another reporting entity.
- **QC25**. Although a single economic phenomenon can be faithfully represented in multiple ways, permitting alternative accounting methods for the same economic phenomenon diminishes comparability.

US GAAP is an excellent financial reporting scheme because it strikes a good balance between the ability to compare and the ability to accurately report the financial condition and financial position of an economic entity. When trying to implement "comparisons" in software, it is very important to understand the goal of comparability the financial reporting scheme enables.

2.24. Conceptual Framework

The financial accounting conceptual framework created by the FASB contributes to this clear, consistent, logically coherent, and unambiguous terminology and principles by providing a disciplined framework[96] which can be used to think about financial accounting. A discussion of the conceptual framework in a FASB special report states in part the objectives of such a conceptual framework:

- Providing a set of common premises as a basis for discussion
- Provide precise terminology
- Helping to ask the right questions

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[95] FASB, *Statement of Financial Accounting Concepts No. 8*, page 19, http://www.fasb.org/cs/BlobServer?blobcol=urldata&blobtable=MungoBlobs&blobkey=id&blobwhere=1175822892635&blobheader=application/pdf

[96] Per FASB Special Report, *The Framework of Financial Accounting Concepts and Standards* (1998)

- Limiting areas of judgment and discretion and excluding from consideration potential solutions that are in conflict with it
- Imposing intellectual discipline on what traditionally has been a subjective and ad hoc reasoning process

However, given the idiosyncratic tendencies of humans, interpretations which reflect the arbitrary peculiarities of individuals can sometimes slip in or mistakes can be made when expressing such terminology. Further, parts of our understanding of financial reporting can be incorrect and can evolve and improve and may even simply change over time.

2.25. Forward Looking Information

Some criticize conventional accounting saying that information provided by such systems is backwards-looking and not useful in managing a business. While these conventional systems provide a reliable record of past financial performance and current financial status, those systems tend to not provide adequate insights necessary for future decision making such as strategic planning. Further, some question the relevance of this information to investors. Others argue that conventional accounting systems do not adequately communicate how a business creates value.

When information technology professionals and business systems analysts first implemented computer-based accounting systems in the 1950s, they essentially digitized the manual tasks and processes performed by accountants at that time. This included only parts of Pacioli's *Summa*[97]. Other parts of Pacioli's Venetian Method of double-entry bookkeeping summarized in the *Summa* were simply left out. The reason for this was that these information technology professionals and business systems analysts implementing computerized accounting took advice from accountants who had never read the *Summa* and only operated those manually implemented systems because human 'computers' were the only option available at that time. Given the limitations of these human 'computers' only a sub-optimal set of the Venetian Method was used during this manual era of accounting and now the computer era of accounting is sub-optimal as a result.

If someone had taken the time to revisit the *Summa*, they would have discovered the Ricordance[98], recognized its value, and perhaps implemented that mechanism.

Essentially, the Ricordance transforms the currently historical-oriented accounting process into what Pacioli had originally envisioned, which indeed involved future-oriented information.

Business management encompasses the handling of all aspects of financial and business contracts associated with that business. It involves the inception, the life cycle, and the management of both financial and business contracts. The Ricordance proves beneficial in managing these events in relation to time, as it aids in organizing all this information on a timeline.

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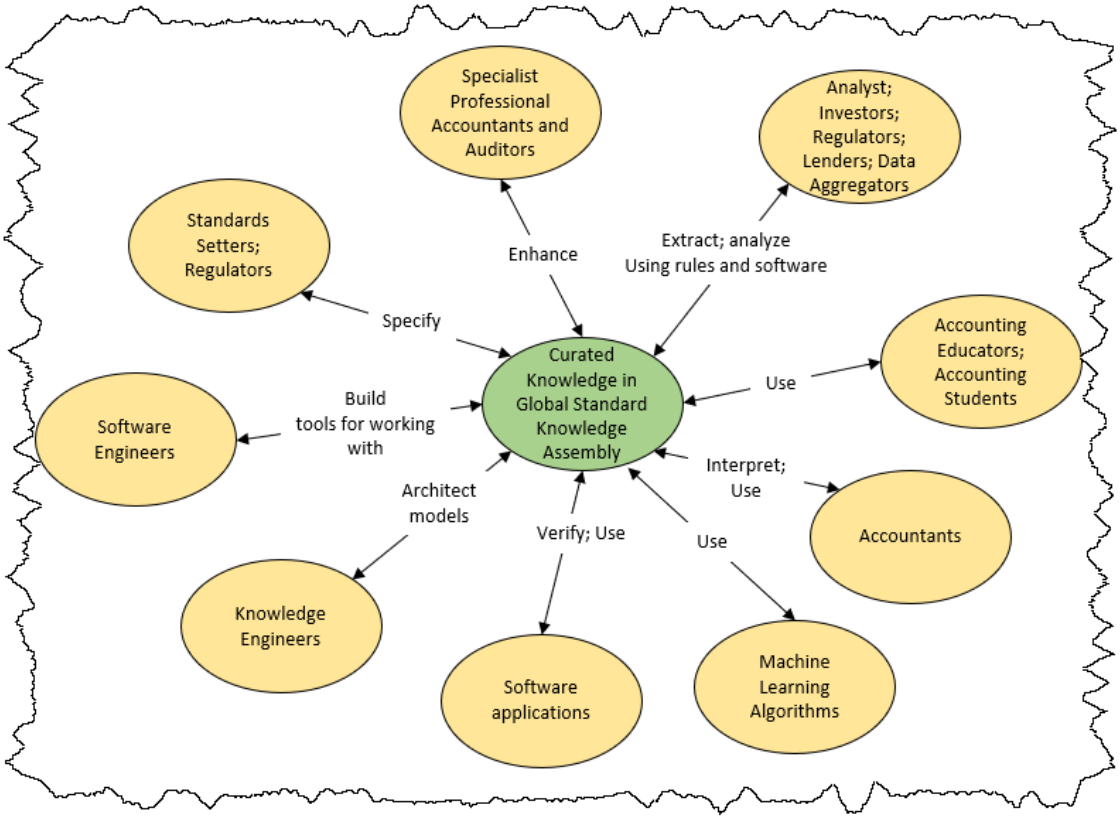
[97] Wikipedia, *Summa de Arithmetica*, https://en.wikipedia.org/wiki/Summa_de_arithmetica

[98] The Accounting Historian's Journal, *Pacioli's forgotten book: The Merchant's Ricordanze*, https://egrove.olemiss.edu/aah_journal/vol39/iss2/3/

Utilizing the Ricordance allows for not only backwards-looking retrospective accounting but also forward-looking prospective analysis. This is made possible by the information provided by the Ricordance about future financial and business contracts, and the impact of these resources and obligations on a business.

2.26. Stakeholders

The system is not a collection of separate silos; rather the system is more like a chain or supply chain (stakeholders) of a system; curated machine-readable knowledge represented in standard format for an area of knowledge (stakeholders).



2.27. Accounting

The following are important aspects of accounting. There tend to be three categories of accounting:

- Financial accounting
- Management (a.k.a. cost) account
- Tax accounting

The bookkeeping process and the accounting language fundamental tend to be the same across all categories of accounting but the terms used might be different.

2.27.1. Facts

Facts are statements about the numbers and words that are provided by an economic entity within a financial report. For example, the financial report might state "assets for the consolidated legal entity Microsoft as of June 20, 2017 was $241,086,000,000 expressed in US dollars and rounded to the nearest millions of dollars."

Words and numbers are used to convey information about the status and performance of an economic entity.

Accountants creating financial reports provide both quantitative information and qualitative information to convey the financial status and performance of an economic entity.

Quantitative information includes actual numbers to disclose an amount or to show a change. For example, "net income for the year was $1,000,000" is quantitative information.

Qualitative information includes providing information in other ways such as using relative terms. For example, disclosing an entity's objective for holding or issuing derivative instruments, background information necessary for understanding those instruments, strategies used to meet those objectives, and information helpful in understanding derivative activity is qualitative information.

2.27.2. Ledgers

Accountants have a special name for the spreadsheets, or tables, that these farmers invented. Accountants call these *ledgers*[99]. A ledger is simply a place where you record information such as transactions. There are a number of different types of ledgers that accountants use. General ledgers[100] tend to be double-entry and capture numeric information. Special ledgers, or subsidiary ledgers, are also generally double-entry and are basically special purpose ledgers for recording specific classes of transactions. For example, a sales ledger is used to record sales transactions of an economic entity and a purchases ledger is used to record purchases of an economic entity.

2.27.3. Journals

A ledger and a journal are not the same thing but are sometimes confused. Journals are the original lists of transactions. Ledgers summarize transactions, generally by account.

2.27.4. Journal

Facts related to transactions, events, circumstances, and other economic phenomenon pertaining to an economic entity are recorded in journals.

In my prior accounting process automation example, I provided a journal represented using the XBRL Global Ledger technical syntax[101].

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[99] Wikipedia, Ledger, https://en.wikipedia.org/wiki/Ledger
[100] Wikipedia, General Ledger, https://en.wikipedia.org/wiki/General_ledger
[101] Accounting Process Automation, *XBRL Global Ledger Format*, http://xbrlsite.azurewebsites.net/2020/master/automation/xbrl-gl-JournalEntries-Instance.xml

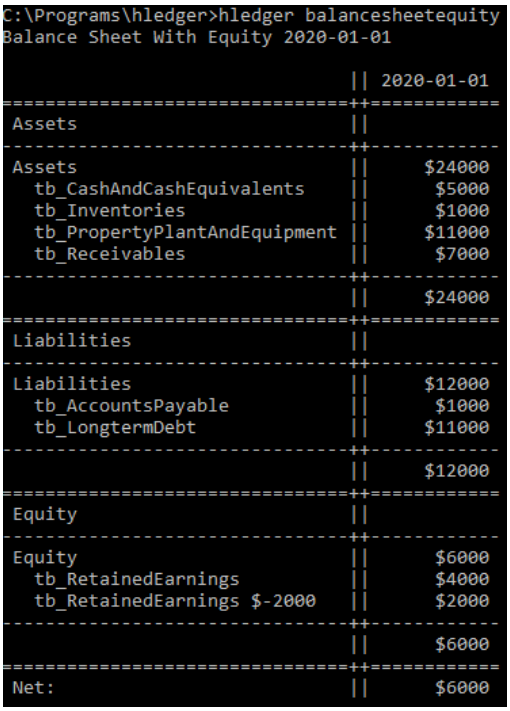
Those same transactions were also represented using XBRL Dimensions technical syntax[102]. For this implementation I used typed dimensions.

To those first two examples, I added the same journal entries using the plain text accounting journal format[103].

Further, to better document the entries I added a PDF of a printout of the details of the journal entries[104] and a screen shot of the database table which contains the journal entries itself[105].

What is interesting is that you can then run the journal entries through hledger which summarizes the transactions into the form of a basic balance sheet, income statement, and cash flow statement.

Here you see my first attempt at generating a balance sheet, income statement, and cash flow statement: (I don't have all of these correct yet; have not done the closing entries)



```
C:\Programs\hledger>hledger balancesheetequity
Balance Sheet With Equity 2020-01-01

                               || 2020-01-01
===============================++============
 Assets                        ||
-------------------------------++------------
 Assets                        ||      $24000
   tb_CashAndCashEquivalents   ||       $5000
   tb_Inventories              ||       $1000
   tb_PropertyPlantAndEquipment||      $11000
   tb_Receivables              ||       $7000
-------------------------------++------------
                               ||      $24000
===============================++============
 Liabilities                   ||
-------------------------------++------------
 Liabilities                   ||      $12000
   tb_AccountsPayable          ||       $1000
   tb_LongtermDebt             ||      $11000
-------------------------------++------------
                               ||      $12000
===============================++============
 Equity                        ||
-------------------------------++------------
 Equity                        ||       $6000
   tb_RetainedEarnings         ||       $4000
   tb_RetainedEarnings $-2000  ||       $2000
-------------------------------++------------
                               ||       $6000
===============================++============
 Net:                          ||       $6000
```

[102] Accounting Process Automation, *XBRL dimensions technical syntax*, http://xbrlsite.azurewebsites.net/2020/master/automation/xbrl-typedMembers-JournalEntries-Instance.xml

[103] Accounting Process Automation, Plain Text Accounting Journal Format, http://xbrlsite.azurewebsites.net/2020/master/automation/TrialBalance.dat.txt

[104] Accounting Process Automation, *Human Readable PDF of journal entries*, http://xbrlsite.azurewebsites.net/2020/master/automation/rptGeneralJournalByEntry.pdf

[105] Accounting Process Automation, *Human Readable JPEG of the database table containing the journal entries*, http://xbrlsite.azurewebsites.net/2020/master/automation/JournalEntriesInDatabase.jpg

```
C:\Programs\hledger>hledger is
Income Statement 2019-12-31-2020-01-01

                          || 2019-12-31-2020-01-01
==========================++=======================
 Revenues                 ||
--------------------------++-----------------------
 Revenue:tb_Sales         ||                 $4000
--------------------------++-----------------------
                          ||                 $4000
==========================++=======================
 Expenses                 ||
--------------------------++-----------------------
 Expense:tb_CostsOfSales  ||                 $2000
--------------------------++-----------------------
                          ||                 $2000
==========================++=======================
 Net:                     ||                 $2000
```

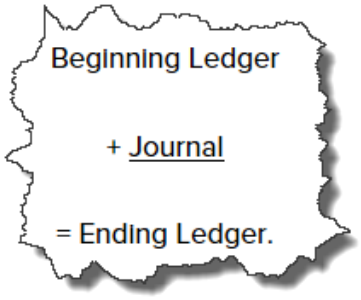
```
C:\Programs\hledger>hledger cf
Cashflow Statement 2019-12-31-2020-01-01

                                    || 2019-12-31-2020-01-01
====================================++=====================
 Cash flows                         ||
------------------------------------++---------------------
 Assets:tb_CashAndCashEquivalents   ||               $10000
 Assets:tb_Inventories              ||                $3000
 Assets:tb_PropertyPlantAndEquipment||                $6000
------------------------------------++---------------------
                                    ||               $19000
```

2.27.5. Ledgers and Journals, Stocks and Flows

Another important piece of double-entry accounting is explained well in David Ellerman's article, *The Math of Double-Entry Bookkeeping: Part II (vectors)*, is ledgers and journals[106].

This is the relationship between a ledger and a journal:



Ledgers summarized balances. For example, the general ledger summarizes account balances. Journals record the transactions which make up the changes between ledger balances. Other terms used for the relationship shown above are "roll forward" or "movements" or "stocks and flows". All three of these terms basically explain the following equation:

"Beginning balance + Additions - Subtractions = Ending balance"

Balance sheet accounts are stocks. Roll forwards of the beginning and ending balances of balance sheet accounts are flows. The income statement is a flow of net income (loss). The cash flow statement is a roll forward of the net change in cash and cash equivalents. The statement of changes in equity is a roll forward of equity accounts.

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[106] David Ellerman, *The Math of Double-Entry Bookkeeping: Part II (vectors)*, http://www.ellerman.org/the-math-of-double-entry-bookkeeping-part-ii-vectors/

Many transactions, events, circumstances, and other phenomenon are recorded as transactions in a journal, make their way to a ledger, and then end up in the primary financial statements or within disclosures which detail the line items of the primary financial statements. Much of this information is part of the two trees which make up the roll ups of "Assets" and "Liabilities and Equity". However, there are other trees that can make up the complete "forest" of a financial report.

2.27.6. Accounts

Journal entries relate to the economic entity being accounted for, some calendar period, and an account from the chart of accounts.

Both hledger and Ledger let you put in whatever accounts you want. You can add accounts on the fly. I was able to use XBRL element names as the account names.

What would be great is if you could constrain what accounts are used by specifying an XBRL taxonomy[107]. (Here is a human readable version[108]. Here is the master version in Excel[109].) For example, here is a not-for-profit chart of accounts that I created.

Line	Label	Object Class	Period Type	Balance	Report ElementName
1	1110 - Unified Chart of Accounts	Network			http://www.xbrlsite.com/ucoa/role/UnifiedChartOfAccounts
2	Assets	Concept (Monetary)	As Of	Debit	nfp:Assets
3	Cash and Cash Equivalents	Concept (Monetary)	As Of	Debit	nfp:CashAndCashEquivalents
4	Cash in bank-operating	Concept (Monetary)	As Of	Debit	ucoa:CashInBankOperating
5	Cash in bank-payroll	Concept (Monetary)	As Of	Debit	ucoa:CashInBankPayroll
6	Petty cash	Concept (Monetary)	As Of	Debit	ucoa:PettyCash
7	Savings and short-term investments	Concept (Monetary)	As Of	Debit	ucoa:SavingsAndShortTermInvestments
8	Receivables	Concept (Monetary)	As Of	Debit	nfp:Receivables
9	Accounts receivable	Concept (Monetary)	As Of	Debit	ucoa:AccountsReceivable
10	Doubtful accounts allowance	Concept (Monetary)	As Of	Credit	ucoa:DoubtfulAccountsAllowance
11	Contributions receivable	Concept (Monetary)	As Of	Debit	ucoa:ContributionsReceivable
12	Pledges receivable	Concept (Monetary)	As Of	Debit	ucoa:PledgesReceivable
13	Doubtful pledges allowance	Concept (Monetary)	As Of	Credit	ucoa:DoubtfulPledgesAllowance
14	Discounts - long-term pledges	Concept (Monetary)	As Of	Credit	ucoa:DiscountsLongTermPledges
15	Grants receivable	Concept (Monetary)	As Of	Debit	ucoa:GrantsReceivable
16	Discounts - long-term grants	Concept (Monetary)	As Of	Credit	ucoa:DiscountsLongTermGrants
17	Other receivables	Concept (Monetary)	As Of	Debit	ucoa:OtherReceivables
18	Employee and trustee receivables	Concept (Monetary)	As Of	Debit	ucoa:EmployeeAndTrusteeReceivables
19	Notes/loans receivable	Concept (Monetary)	As Of	Debit	ucoa:NotesLoansReceivable
20	Doubtful notes/loans allowance	Concept (Monetary)	As Of	Credit	ucoa:DoubtfulNotesLoansAllowance
21	Inventories	Concept (Monetary)	As Of	Debit	nfp:Inventories
22	Inventories for sale	Concept (Monetary)	As Of	Debit	ucoa:InventoriesForSale
23	Inventories for	Concept (Monetary)	As Of	Debit	ucoa:InventoriesForUse

If there was a way to specify which chart of accounts must be used and the reporting taxonomy plus reporting style used.

2.27.7. Chart of Accounts

A chart of accounts is simply a listing of the account names that an economic entity uses to record transactions in its journals and ledgers. An economic entity tailors its chart of accounts to meet the specific unique needs of the economic entity.

Examples of account names that might be in a chart of accounts might be:

- Cash in bank

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[107] Unified Chart of Accounts, XBRL, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/nfp/ucoa/ucoa.xsd

[108] Unified Chart of Accounts, Human readable, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/nfp/ucoa/ucoa_ModelStructure.html

[109] Unified Chart of Accounts, Master Excel version, https://netsuiteorg.atlassian.net/wiki/spaces/PB/pages/108729619/Unified+Chart+of+Accounts+UCOA

- Petty cash
- Other cash and cash equivalents
- Trade accounts receivable
- Finished goods inventory
- Work-in-progress inventory
- Raw materials inventory
- Land
- Buildings
- Equipment
- Trade accounts payable
- Long-term debt
- Retained earnings
- Sales revenue
- Depreciation and amortization
- Income tax expense

However, although an economic entity uses a unique chart of accounts internally, when information is reported that information is grouped following some financial reporting scheme.

2.27.8. Canonical Chart of Accounts

Over 40 years of experience with accountants and accounting information systems has demonstrated that the average accountant has a hard time setting up a chart of accounts properly in an accounting system. Imagine if accounting systems provided industry specific chart of accounts, or a canonical chart of accounts, for specific industries that could then be modified by accountants to meet the individual needs of specific reporting economic entities. Saying this another way; it is very rare that the person that operates an accounting system also has the skills necessary to set up that accounting system efficiently. Using canonical charts of accounts could solve this problem.

2.27.9. Account Types

Accounting systems generally allow for the assignment of a "type" to each account so that accounts can be processed correctly. However, these types tend to be too general, incomplete, and many times informal in nature.

Accounting systems have a "chart of accounts". That chart of accounts is used to group transactions within an accounting system. Accounts in a chart of accounts can be grouped or categorized into "types". Different accounting systems have different mechanisms for assigning types. It has been my observation over 40 years of dealing with this that:

1. Some systems are more or less complete than others.
2. Some systems are more or less formal than others.

3. Pretty much all systems have ONE scheme of "types" when they really should have more flexibility for configuring the types.

Commonly, the types you see are:

- Assets
- Liabilities
- Equity
- Revenues
- Expenses

You use that, then there is no way to distinguish, say, a "Current Asset" from a "Noncurrent Asset". There is no way to properly reflect "Income tax expense (refund)".

Basically, there is no real "connection" between the accounting system and a properly created external financial report or an internal management report or a properly created tax related information. All that is done outside of the accounting system. Why? Note the word "system". What is the accounting system supposed to do? I contented that a significant job is to summarize information for reporting. Having to use something like Excel to fill the gap.

What is needed to make this full system work is:

1. Accounting system (transactions)
2. Accounts and types (trial balance)
3. Report writer (turns trial balance into a set of reports)
4. Reports (external financial reports, internal management and cost accounting reports, tax reporting related reports)

All these four pieces should be connected, and can be connected.

A more effective set of "types" would be, in my view, as follows. I have been struggling with whether this should be ONE LIST for both US GAAP and IFRS or TWO SEPARATE LISTS. I have pretty much reached the conclusion that it really does not matter because you can map the two sets if you need to use them together for some reason or use preferred labels to overcome things like the use of "Revenues" in US GAAP and "Income" in IFRS; "Net Income (Loss)" in US GAAP and "Profit (Loss)" in IFRS; and such.

This is my view of the different "types"[110] that are organized into a number of different reporting styles.

[110] Account Types, http://accounting.auditchain.finance/fac/fac_ModelStructure.html

17	FAC-11-Balance Sheet Classified	Network			http://www.xbrlsite.com/fac/role/BalanceSheetClassified
18	**Balance Sheet Classified [Table]**	Hypercube			fac:BalanceSheetClassifiedTable
19	**Balance Sheet [Line Items]**	LineItems			fac:BalanceSheetLineItems
20	Assets [Roll Up]	Abstract			fac:AssetsRollUp
21	Current Assets	Concept (Monetary)	As Of	Debit	fac:CurrentAssets
22	Noncurrent Assets	Concept (Monetary)	As Of	Debit	fac:NoncurrentAssets
23	Assets	Concept (Monetary)	As Of	Debit	fac:Assets
24	Liabilities Equity [Roll Up]	Abstract			fac:LiabilitiesEquityRollUp
25	Liabilities [Roll Up]	Abstract			fac:LiabilitiesRollUp
26	Current Liabilities	Concept (Monetary)	As Of	Credit	fac:CurrentLiabilities
27	Noncurrent Liabilities	Concept (Monetary)	As Of	Credit	fac:NoncurrentLiabilities
28	Liabilities	Concept (Monetary)	As Of	Credit	fac:Liabilities
29	Commitments And Contingencies	Concept (Monetary)	As Of	Credit	fac:CommitmentsAndContingencies
30	Temporary Equity	Concept (Monetary)	As Of	Credit	fac:TemporaryEquity
31	Equity [Roll Up]	Abstract			fac:EquityRollUp
32	Equity Attributable To Parent	Concept (Monetary)	As Of	Credit	fac:EquityAttributableToParent
33	Equity Attributable To Noncontrolling Interest	Concept (Monetary)	As Of	Credit	fac:EquityAttributableToNoncontrollingInterest
34	Equity	Concept (Monetary)	As Of	Credit	fac:Equity
35	Liabilities And Equity	Concept (Monetary)	As Of	Credit	fac:LiabilitiesAndEquity
36	FAC-12-Balance Sheet Classified 4	Network			http://www.xbrlsite.com/fac/role/BalanceSheetClassified4

2.27.10. Trial Balance

A trial balance is simply a total of all journal entries (transactions) summarized by chart of accounts account. The sum of all transactions will always be zero:

Trial Balance [Roll Up]	Period [Axis]	
	2020-12-31	2019-12-31
Trial Balance [Roll Up]		
Cash and Cash Equivalents	4,000.00	3,000.00
Receivables	2,000.00	1,000.00
Inventories	1,000.00	1,000.00
Property, Plant and Equipment	6,000.00	1,000.00
Accounts Payable	(1,000.00)	(1,000.00)
Long-term Debt	(6,000.00)	(1,000.00)
Retained Earnings	(6,000.00)	(4,000.00)
Check Sum	.00	.00

2.27.11. Real versus Nominal (Temporary) Accounts

There are two types of accounts in a chart of accounts: **real** (or permanent) and **nominal** (or temporary).

Real account balances are not closed at the end of an accounting year; they begin each year with the ending balance of the prior year. Balance sheet accounts are real accounts.

Nominal account balances are closed at the end of an accounting year; they begin each year with a zero balance. Income statement accounts are nominal accounts.

2.27.12. Roll Forward of Real Accounts

A trial balance provides a summary of transactions by account. After a set of books is closed, every balance sheet account (each real account) has a set of transactions that flow through that account. Two accounts are of particular note.

All the transactions that flow through the balance sheet account "Cash and Cash Equivalents" form the items that will appear on the cash flow statement if the direct method is used. For example:

Cash and Cash Equivalents [Roll Forward]	Period [Axis] 2020-01-01 - 2020-12-31
Cash and Cash Equivalents [Roll Forward]	
Cash and Cash Equivalents, Beginning Balance	3,000.00
Collection of Receivables	3,000.00
Payment of Accounts Payable	(2,000.00)
Additional Long-term Borrowings 2	6,000.00
Repayment of Long-term Borrowings 2	(1,000.00)
Capital Additions of Property, Plant and Equipment 2	(5,000.00)
Cash and Cash Equivalents, Ending Balance	4,000.00

Each item in the roll forward above would be grouped on the cash flow statement using the direct method as either cash flows from operating, investing, or financing activities. The beginning and ending cash and cash equivalents balance ties the beginning balance sheet to the ending balance sheet of an accounting period.

Further, all the transactions that flow through the balance sheet account "Retained Earnings" form the items that will appear on the statement of changes in equity. For example,

Retained Earnings [Roll Forward]	Period [Axis] 2020-01-01 - 2020-12-31
Retained Earnings [Roll Forward]	
Retained Earnings, Beginning Balance	4,000.00
Net Income (Loss)	2,000.00
Retained Earnings, Ending Balance	6,000.00

All the transactions that flow through the item "Net Income (Loss)" is the sum of all the transactions of the nominal accounts. The line item "Net Income (Loss)" ties the beginning and ending statement of changes in equity to both the balance sheet and to the income statement.

This forms the four statement model framework.

While a roll forward is not generally reported for each and every balance sheet account in a set of external financial statements; it is the case that every balance sheet account does have a roll forward of transactions which can be grouped into important financial information. For example, accounts receivable:

Receivables [Roll Forward]	Period [Axis] 2020-01-01 - 2020-12-31
Receivables [Roll Forward]	
Receivables, Beginning Balance	1,000.00
Sales 2	4,000.00
Collection of Receivables 2	(3,000.00)
Additions to Allowance for Bad Debts	.00
Bad Debts Written Off	.00
Receivables, Ending Balance	2,000.00

Long term debt:

Long-term Debt [Roll Forward]	Period [Axis] 2020-01-01 - 2020-12-31
Long-term Debt [Roll Forward]	
Long-term Debt, Beginning Balance	1,000.00
Additional Long-term Borrowings	6,000.00
Repayment of Long-term Borrowings	(1,000.00)
Long-term Debt, Ending Balance	6,000.00

Finally, if you take all of the roll forward groupings of all the real accounts after the accounts have been closed for an accounting period; the total of those balance sheet real account roll forward groupings would be zero just like the general ledger trial balance:

Changes Summary [Roll Up]	Period [Axis] 2020-01-01 - 2020-12-31
Changes Summary [Roll Up]	
Collection of Receivables	3,000.00
Payment of Accounts Payable	(2,000.00)
Additional Long-term Borrowings 2	6,000.00
Repayment of Long-term Borrowings 2	(1,000.00)
Capital Additions of Property, Plant and Equipment 2	(5,000.00)
Sales 2	4,000.00
Collection of Receivables 2	(3,000.00)
Additions to Allowance for Bad Debts	.00
Bad Debts Written Off	.00
Purchases of Inventory for Sale	2,000.00
Costs of Sales 2	(2,000.00)
Inventory Written Off	.00
Capital Additions of Property, Plant and Equipment	5,000.00
Depreciation and Amortization 2	.00
Property, Plant and Equipment Written Off	.00
Purchases of Inventory for Sale 2	(2,000.00)
Payment of Accounts Payable 2	2,000.00
Additional Long-term Borrowings	(6,000.00)
Repayment of Long-term Borrowings	1,000.00
Net Income (Loss)	(2,000.00)
Check Sum Changes	.00

Many accountants tend to not manage this information effectively and end up having to create this information at the end of an accounting cycle. However, if this information were entered at the point of transaction entry, then a proper cash flow statement and statement of changes in equity can be generated along with a balance sheet and income statement.

2.27.13. Roll Forward Grouping Codes

The notion of a roll forward grouping code is informally implemented by Workday informally using the notion of a "work tag"[111]. Someone else refers to the same thing as "transaction verbs"[112]. The notion of roll forward grouping codes will be discussed in detail in later sections of this document.

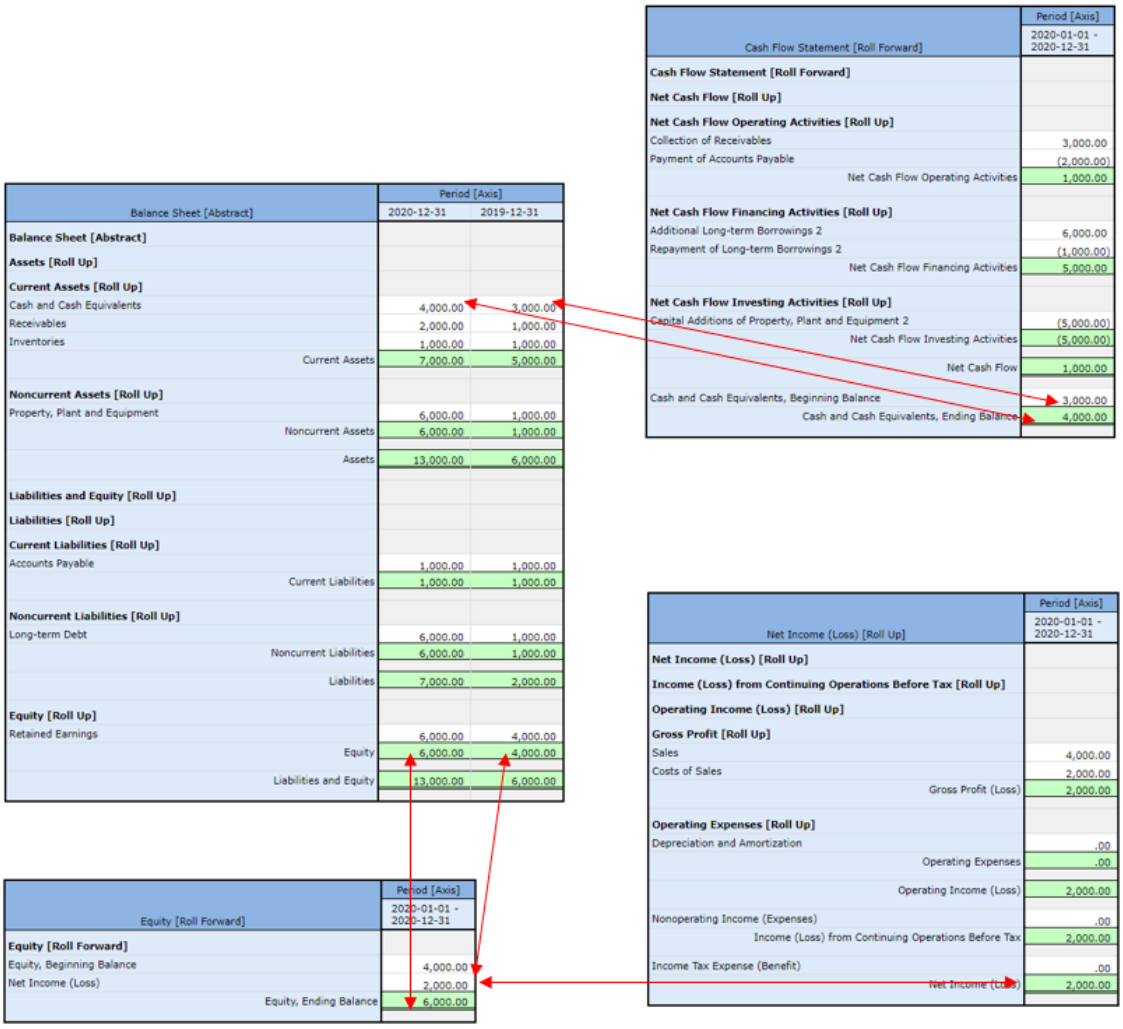
2.28. Reporting

Reporting is the process of turning recorded business event information represented using accounting transactions into a financial statement.

[111] Workday, *Tales of the Cloud: The Story of Worktags*, https://blog.workday.com/en-us/2012/tales-of-the-cloud-the-story-of-worktags.html
[112] GitHub, Lodgeit Labs, https://github.com/lodgeit-labs/accounts-assessor

2.28.1. Four Statement Model

As previously mentioned, every financial reporting scheme has a characteristic that is referred to as "articulation". Articulation is the notion that the elements of a financial statement are interrelated and therefore depend on one another and so the four core financial statements; the balance sheet, the income statement, the statement of changes in equity and the cash flow statement are all mathematically interrelated to one another. Articulation is explained very methodically by the FASB in SFAC 6[113]. The graphic below shows the interrelated nature, the articulation, of the core four financial statements:



2.28.2. Reporting Styles

How the "branches" are organized within the "tree" of information into which the "leaves" from the chart of accounts are put is referred to as a reporting style. US

[113] ibid, page 21 – 22, "Interrelation of Elements-Articulation"

GAAP has a set of reporting styles[114]. Similarly, IFRS has a set of reporting styles[115]. The same sort of pattern exists for every financial reporting scheme.

2.28.3. Forests, Trees, Branches, and Leaves

I explained graphs, forests, trees, branches, and leaves in my document *Accounting Process Automation using XBRL*[116].

A **tree**[117] is a special type of graph. A tree is what is called an undirected graph because the items in a tree are connected by exactly one path. This is important to understand because it means that trees are safer than other types of graphs which can contain cycles which generally need to be avoided because they can cause problems. For example, one type of cycle is an infinite loop.

A **forest** is a disjointed union of trees. Trees have **branches**. Trees have **leaves**.

A chart of accounts will not have an account or ledger for either "Assets" or "Liabilities and Equity". "Assets" and "Liabilities and Equity" are branches. For example:

- ***Assets***
  - ***Current assets***
    - **Cash and cash equivalents**
      - Cash in bank
      - Petty cash
      - Other cash and cash equivalents
    - **Receivables**
      - Trade accounts receivable
    - **Inventories**
      - Finished goods inventory
      - Work-in-progress inventory
      - Raw materials inventory
  - ***Noncurrent assets***
    - **Property, plant and equipment**
      - Land
      - Buildings
      - Equipment
    - **Long-term investments**

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[114] US GAAP Reporting Styles, http://www.xbrlsite.com/2018/10K/US-GAAP-Reporting-Styles.pdf
[115] IFRS Reporting Styles, http://www.xbrlsite.com/2018/IFRS/IFRS-Reporting-Styles.pdf
[116] Charles Hoffman, *Accounting Process Automation Using XBRL*, page 5, http://xbrlsite.azurewebsites.net/2018/Library/AccountingProcessAutomationUsingXBRL.pdf
[117] Wikipedia, *Tree (Graph Theory)*, https://en.wikipedia.org/wiki/Tree_(graph_theory)

- Equity securities
- Debt securities

The items above in bold italics are branches in the tree of assets. "Assets" is the root branch. "Current assets" and "Noncurrent assets" are always branches, you never post transactions to those, they are not accounts and they don't have ledgers. Depending upon how a chart of accounts is set up something could be a branch or it could be a leaf. For example, in the example above, "Cash and cash equivalents" is likely a branch with three leaves for the accounts to which transactions are posted.

2.28.4. Report Writer

Essentially, an XBRL taxonomy can be viewed somewhat as report writer metadata. The XBRL taxonomy specifies the high-level concepts that constitute a financial report and how those high-level concepts are organized (i.e. a reporting style) within the set of financial statements. The XBRL taxonomy also specifies the mathematical computations of the report.

The "leaves" or the items within the chart of account roll up to the "branches" which make up the subtotals and totals of a report. So, for example, on the actual report you see the line items "Cash and Cash Equivalents" and "Accounts Receivable" and "Inventories" as contrast to the more detailed items which are contained within the chart of accounts. Perhaps some other internal report shows both the higher level intermediate totals/subtotals and the chart of account items that make up those intermediate totals/subtotals.

Roll up:

Balance Sheet [Abstract]	Period [Axis]	
	2018-12-31	2017-12-31
Balance Sheet [Abstract]		
Assets [Roll Up]		
Current Assets [Roll Up]		
Cash and Cash Equivalents	4,000	3,000
Accounts Receivable	2,000	1,000
Inventories	1,000	1,000
Current Assets	7,000	5,000
Noncurrent Assets [Roll Up]		
Property, Plant, and Equpment, Net	6,000	1,000
Noncurrent Assets	6,000	1,000
Assets	13,000	6,000

XBRL calculation relations rule:

Label	Rendered		Reported	Calculated	Balance	Decimals	Message
Assets [Roll Up]							
Current Assets [Roll Up]							
Cash and Cash Equivalents	4,000	+	4,000	4,000	DR	INF	
Accounts Receivable	2,000	+	2,000	2,000	DR	INF	
Inventories	1,000	+	1,000	1,000	DR	INF	
Current Assets	7,000	+	7,000	7,000	DR	INF	OK
Noncurrent Assets [Roll Up]							
Property, Plant, and Equpment, Net	6,000	+	6,000	6,000	DR	INF	
Noncurrent Assets	6,000	+	6,000	6,000	DR	INF	OK
Assets	13,000		13,000	13,000	DR	INF	OK

The basic equation for a roll up is "A + B + *n* = Total", where some value A plus some value B plus *n* other values = the roll up total.

Roll forward:

Changes in ledger balances or the "flows" between a stock at two points in time or the equation "Beginning balance + changes = Ending Balance" is represented in the form of what accountants commonly refer to as a "roll forward" or "movements analysis". For example, the following is a basic roll forward:

Long-term Debt [Roll Forward]	Period [Axis] 2020-01-01 - 2020-12-31
Long-term Debt [Roll Forward]	
Long-term Debt, Beginning Balance	1,000.00
Additional Long-term Borrowings	6,000.00
Repayment of Long-term Borrowings	(1,000.00)
Long-term Debt, Ending Balance	6,000.00

Adjustment:

Adjustments to a ledger balance to correct an error, the equation "Originally stated balance + Adjustments = Restated Balance". For example, the following is a basic adjustment:

Component: (Network and Table)	
Network	FA - Statement - **Changes in Equity, Prior Period Adjustments**
Table	Statement of Changes in Equity, Prior Period Adjustments [Table]

Reporting Entity [Axis]	1234567890 http://regulator.gov/id	
Legal Entity [Axis]	Consolidated Entity [Member]	
Reporting Scenario [Axis]	Actual [Member]	
Unit [Axis]	USD	
		Period [Axis]
Statement of Changes in Equity, Prior Priod Adjustments [Li...	Report Date [Axis]	2010-01-01/2010-12-31
Retained Earnings (Accumulated Losses), Prior Period Adjustments [Adjustment]		
Retained Earnings (Accumulated Losses), Originally Stated	Reported as of February 22, 2010 [Member]	2,000
Retained Earnings (Accumulated Losses), Prior Period Errors	Reported as of March 18, 2011 [Member]	500 [1]
Retained Earnings (Accumulated Losses), Changes in Accounting Policies	Reported as of March 18, 2011 [Member]	(1,500) [1]
Retained Earnings (Accumulated Losses), Restated	Reported as of March 18, 2011 [Member]	1,000

Again, this shows the mathematical relations more clearly:

Label	Rendered Value	Op	Reported Value	Calculated Value	Balance	Result	Name
Statement of Changes in Equity, Prior Priod Adjustments [Line Items]							gaap:StatementChangesInEquityPriorPriodAdjustmentsLineItems
Retained Earnings (Accumulated Losses), Prior Period Adjustments [Adjustment]							gaap:RetainedEarningsAccumulatedLossesPriorPeriodAdjustmentsAdjustment
Retained Earnings (Accumulated Losses), Originally Stated	2,000	+	2,000		Credit		gaap:RetainedEarningsAccumulatedLosses
Retained Earnings (Accumulated Losses), Prior Period Errors	500	+	500		Credit		gaap:RetainedEarningsAccumulatedLossesPriorPeriodErrors
Retained Earnings (Accumulated Losses), Changes in Accounting	(1,500)	+	-1,500		Credit		gaap:RetainedEarningsAccumulatedLossesChangesInAccountingPolicies
Retained Earnings (Accumulated Losses), Restated	1,000	+	1,000	1,000	Credit	Verified	gaap:RetainedEarningsAccumulatedLosses

2.28.5. Financial Report

The final product or output of the tasks and processes is a financial report. Information from that financial report came from an accounting information system. That report might be audited. That report might be analyzed.

The intent of this section is to explain that financial reports created using this process could look precisely like financial statements created today. Those reports, however, would be created in new ways.

As I understand it, today about 85% of external financial reports created are created using word processors and spreadsheets that have no knowledge of financial reporting. Because these applications have no knowledge of financial reporting, the burden is on the creator of the financial report, the operator of the word processing documents and spreadsheets, to understand financial reporting rules.

It is my view that some of the boring, mundane and mindless tasks involved in the creation of external financial reports can be delegated to automated machine-based processes.

The following is an example of one possible target so that you can get a feel for the quality of the financial reports that I am referring to[118]:

[118] Inline XBRL report example, http://xbrlsite.azurewebsites.net/2020/master/tb/instance-PixelPerfect.html

Balance Sheet

ABC Company, Inc.

(See accompanying notes to the financial statements.)

(in US Dollars)	As of December 31, 2018	As of December 31, 2017
ASSETS		
Current Assets:		
Cash and cash equivalents	$4,000	$3,000
Receivables	2,000	1,000
Inventories	1,000	1,000
Current assets	7,000	5,000
Noncurrent Assets:		
Property, plant, and equipment	6,000	1,000
Noncurrent assets	6,000	1,000
Assets	$13,000	$6,000
LIABILITIES AND EQUITY		
LIABILITIES		
Current liabilities:		
Accounts payable	$1,000	$1,000
Current liabilities	1,000	1,000
Noncurrent liabilities:		
Long-term debt	6,000	1,000
Noncurrent liabilities	6,000	1,000
Liabilities	7,000	2,000
EQUITY		
Retained earnings	6,000	4,000
Equity	6,000	4,000
Liabilities and equity	$13,000	$6,000

Essentially, pixel perfect external financial reports could be created to the extent of the features of HTML 5 and CSS 3 for document publishing. Such a report could be supplemented by something like an Inline XBRL viewer software application[119].

Other rendering alternatives are available that provide far less work but the presentation formats are not pixel perfect. Specific details of a report can be

[119] Inline XBRL report with embedded viewer, http://xbrlsite.azurewebsites.net/2020/master/tb/instance-PixelPerfectWithViewer.html

communicated precisely[120]. Entire HTML-based applications can be created for interacting with a financial report; for example[121],

Statement of Financial Postion, Classified [Line Items]	Period [Axis]	
	2020-12-31	2019-12-31
Assets [Roll Up]		
Current Assets [Roll Up]		
Cash and Cash Equivalents	25,843	29,843
Short-term Investments	17,855	17,440
Receivables	4,833	5,750
Inventories	18,751	12,144
Prepaid Expenses	1,284	1,743
Other Current Assets	3,467	2,588
Current Assets	72,033	69,508
Noncurrent Assets [Roll Up]		
Investments, Noncurrent	84,839	84,839
Property, Plant and Equipment	190,745	189,176
Other Noncurrent Assets	29,803	34,509
Noncurrent Assets	305,387	308,524
Assets	377,420	378,032

While all of these reports are readable by humans, each is also machine readable[122]. In fact, the autogenerated HTML-based reports are generated dynamically using the machine-readable XBRL-based report plus supporting XBRL taxonomies.

Taking all this a step further, machine-readable reports can be interacted with using software applications[123]. These sorts of software applications are a lot like pivot tables with all sorts of robust functionality[124].

However, there are some issues related to some autogenerated financial reports. HTML 5 and CSS 3 currently do not support page layout document oriented flow control[125]. As such, it can be challenging to get a report that works well on the web to also act well as a printed document.

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[120] HTML-based autogenerated representation of financial report, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/nfp/reference-implementation/evidence-package/contents/RenderingSummary.html

[121] Auto-generated financial report, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/nfp/reference-implementation/evidence-package/

[122] Machine-readable raw XBRL instance, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/nfp/reference-implementation/instance.xml

[123] Pesseract working proof of concept, http://pesseract.azurewebsites.net

[124] Self guided tour of XBRL-based financial report, http://xbrlsite.azurewebsites.net/2019/Tour

[125] Quark, The Ugly Duckling No More: Using Page Layout Software to Format DITA Outputs, https://blog.quark.com/2016/10/ugly-duckling-no-using-page-layout-software-format-dita-outputs/

Document Information Typing Architecture[126] (DITA) is a step closer to better layout when page flow is desired. Another option is a word processor document format such as DocBook[127]. DITA is different than DocBook[128]. Another alternative is XSL-FO which does basic page flow but does have limitations; but it is free and can be used to generate a PDF document.

HTML and CSS are suitable and sufficient for browser-oriented rendering of information. To overcome those limitations, the W3C created the Extensible Stylesheet Language Formatting Objects (XSL-FO) to define a collection of pagination semantics for print-oriented rendering.

Exactly which of these alternatives to use for printed financial reports is up in the air. If you don't care about page flow, such as with Inline XBRL documents that are not intended to be printed, then XHTML + XBRL (i.e. Inline XBRL) could work just fine. If you want pixel-perfect rendering, commercial publishing alternatives exist but they tend to be somewhat expensive.

Serializing financial reports to OpenDocument[129] or Microsoft Word is very doable. Even better, outputting to multiple different rendering formats would also be a very good thing.

Are "pretty" financial reports necessary? Sometimes likely yes, other times perhaps not.

2.28.6. Record to Report

Wikipedia describes record to report as follows: "Record to report or R2R is a Finance and Accounting (F&A) management process which involves collecting, processing and delivering relevant, timely and accurate information used for providing strategic, financial and operational feedback to understand how a business is performing.[130]"

Another description of record to report is provided as follows[131]:

"Record to Report (R2R) is a Finance and Accounting (F&A) management process which involves collecting, processing and delivering relevant, timely and accurate information. It provides strategic, financial and operational feedback on how a business is performing. Stakeholders read the feedback and gain insights into whether an organization is performing successfully or not, and if their expectations have been met." The same author describes best practices in record to report[132].

The essence of what I call enhanced record to report can be explained graphically as follows:

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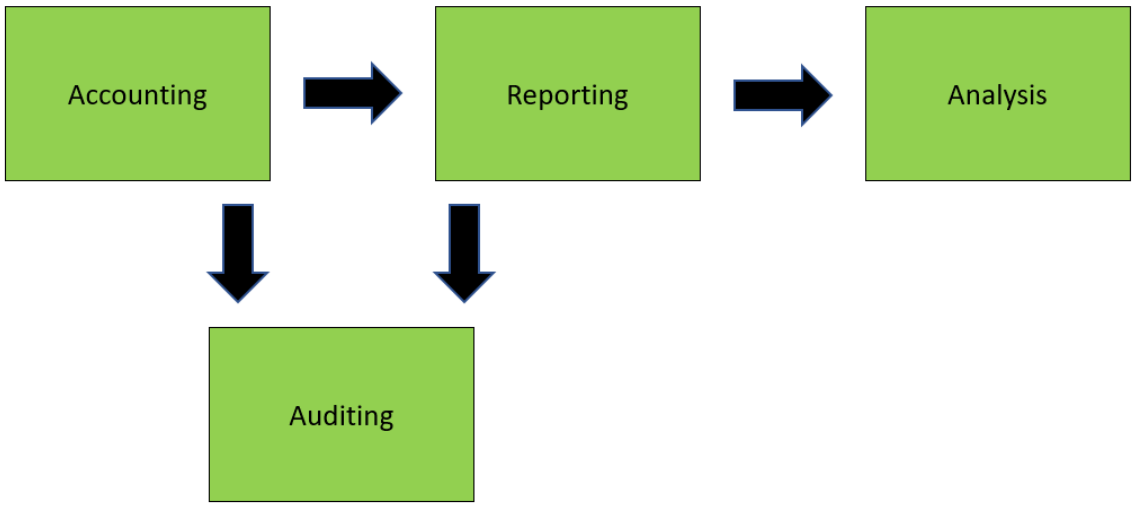
[126] Wikipedia, *Document Information Typing Architecture*, https://en.wikipedia.org/wiki/Darwin_Information_Typing_Architecture
[127] DocBook.org, What is DocBook?, https://docbook.org/whatis
[128] DocBook versus DITA Comparison, https://www.oxygenxml.com/events/2018/DITA_OT_DAY/Radu-Coravu_docbook-vs-dita.pdf
[129] Wikipedia, *OpenDocument*, https://en.wikipedia.org/wiki/OpenDocument
[130] Wikipedia, *Record to Report*, https://en.wikipedia.org/wiki/Record_to_report
[131] Senthil Kumaran, Operations Manager - Finance and Accounting, Invensis Technologies, *What is Record to Report (R2R)*, https://www.invensis.net/blog/finance-and-accounting/what-is-record-to-report/
[132] Senthil Kumaran, Operations Manager - Finance and Accounting, Invensis Technologies, *6 Best Practices for Record-to-Report Process*, https://www.invensis.net/blog/finance-and-accounting/6-best-practices-record-report-process/



- **Accounting**: Accounting information is captured in journals and ultimately posted to ledgers. Special journals may be used to feed the general ledger for specific accounting subsystems.
- **Reporting**: Accounting information is summarized and a specific generally accepted financial reporting scheme is used to report economic entity information to regulators and other appropriate parties. A special purpose financial reporting scheme might also be used sometimes.
- **Auditing (a.k.a. Assurance)**: At times, independent third-party verification is required. When required, an independent public accountant verifies that a financial report is a true and fair representation of the financial position and financial performance of an economic entity.
- **Analysis**: Regulators, investors, analysts, and other such interested parties use reported information to evaluate an economic entity. Period comparisons are often created to evaluate the condition and performance of one economic entity over a period of time. Entity comparisons[133] are often created to compare and contrast one economic entity with one or more other economic entities. Financial ratios are often computed based on reported information. Financial models, such as an unlevered discounted cash flow model[134], might be created to evaluate an economic entity.

The Knowledge Graph Cookbook: Recipes that Work[135], points out that the basic rule is that context information such as tagging and classification of information should take place as soon as possible after content has been created. It is better to add information during financial transaction entry than when a financial report is being created.

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[133] Charles Hoffman, CPA, *Reporting Style Examples*, http://www.xbrlsite.com/2016/fac/v3/Examples/Index.html

[134] Charles Hoffman, CPA, *Representing Unlevered Discounted Cash Flow Model Using XBRL*, http://xbrl.squarespace.com/journal/2018/9/4/representing-unlevered-discounted-cash-flow-model-using-xbrl.html

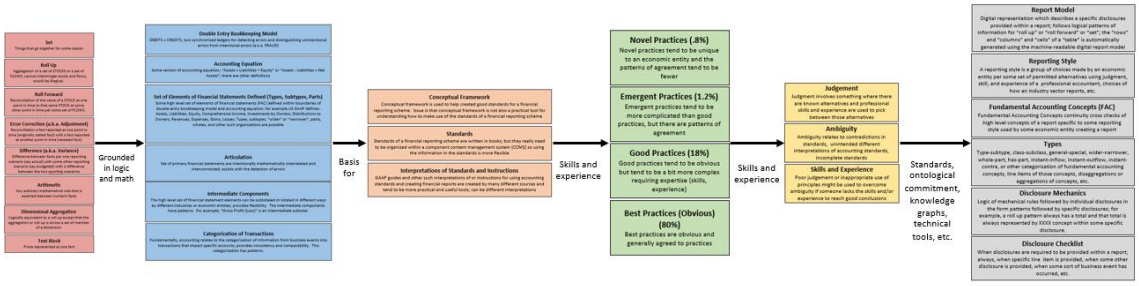
[135] Andreas Blumauer and Helmut Nagy, The Knowledge Graph Cookbook: Recipes that Work, page 56, https://www.poolparty.biz/wp-content/uploads/2020/04/the-knowledge-graph-cookbook.pdf

Again, this is a high-level overview of the very basics of a record to report process. In the real world, economic entities have to deal with complexities such as multiple currencies, consolidating hundreds of subsidiaries which might use different accounting systems, and other such realities.

2.28.7. Digitizing Financial Reporting

A green field project[136] is a project that does not have the constraints of prior work. Imagine what financial accounting, reporting, auditing, and analysis might look like if they were invented and designed today. What if financial reporting schemes were not written in books, but rather created using an ontology-like thing[137]. What if those ontology-like things generated the books that contain conceptual frameworks, standards, interpretations of the standards, instructions for creating financial reports. What if the skills and experience of accountants was more consistent and good practices and best practices were well understood. What if the ambiguity of financial reporting schemes were reduced or even eliminated altogether. What if there was some set of technologies that could be used to create logical systems[138] that worked reliably and did not break? What if good software was created that did its job and was easy for business professionals such as accountants found the software easy to use? What if accountants and software engineers understood the difference between "strings" and "things"?

Here are the moving pieces of the puzzle[139]:



If you had a "green field" and could reinvent financial reporting; would you want to use Microsoft Word and Excel spreadsheets to create financial reports? Would you want to look at the process of creating disclosures that go into such reports as individual "art projects" or would you prefer that the disclosures were more similar to Legos and building a report was putting Lego blocks together, perhaps leveraging software tools for that process? Would you want to be bothered with having to figure out that you made a math error; or would you prefer that a software application would detect such errors and let you fix them; or even better, prevent you from making the error in the first place? Would you want a global standard knowledge graph of accounting rules and software that could provide functionality

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136 Wikipedia, *Green Field Project*, https://en.wikipedia.org/wiki/Greenfield_project

137 *Describing Financial Reporting Rules Using Ontology-like Thing*, https://digitalfinancialreporting.blogspot.com/2023/11/describing-financial-reporting-using.html

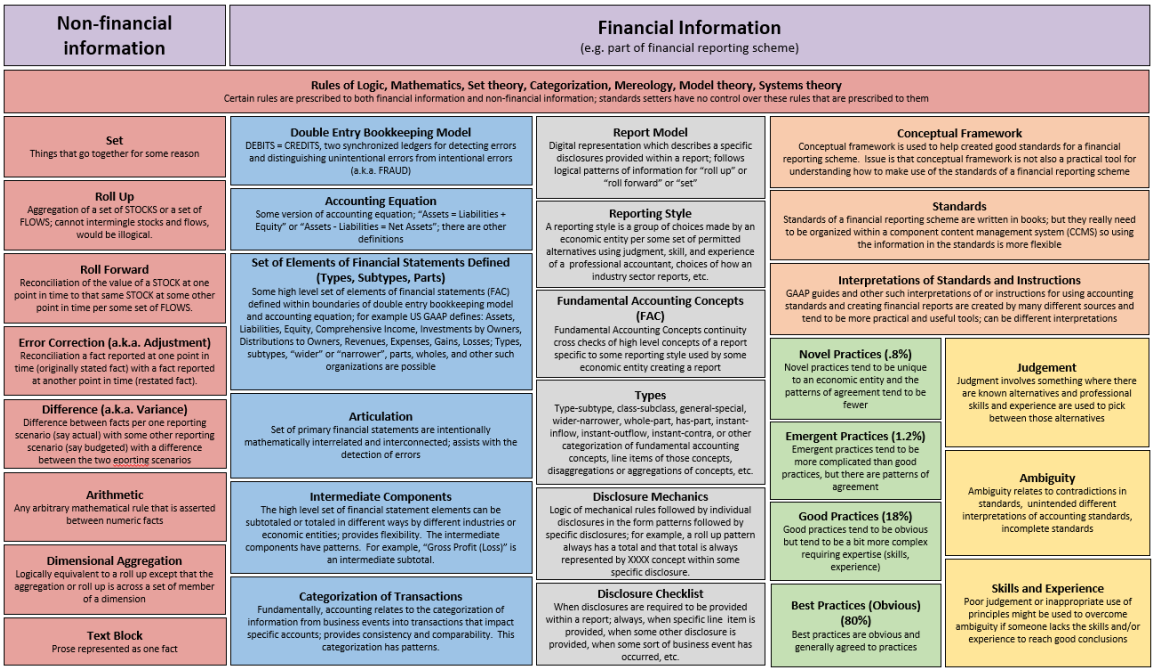
138 *Logical Systems for Professional Accountants*, https://digitalfinancialreporting.blogspot.com/2023/09/logical-systems-for-business.html

139 *Puzzle Pieces of Digital Financial Reporting*, https://digitalfinancialreporting.blogspot.com/2023/11/puzzle-pieces-of-digital-financial.html

that looked like magic to accountants[140]? Would you want explainable and reliable artificial intelligence to augment your accounting skills, making you a better accountant similar to how a calculator makes you better at doing math?

2.28.8. Puzzle Pieces of Financial Reporting[141]

Financial information "behaves" differently from non-financial information in know, specific ways. The logical artifacts need to be understood and considered when digitizing financial reporting. Digital financial reporting can leverage the behaviors of financial information. The following is a summary of the puzzle pieces of financial reporting that need to be considered when digitizing financial reporting[142]:



The details of the fundamental puzzle pieces of digital financial reporting[143] are explained by the *Essence of Accounting*[144], *Financial Report Knowledge Graph*[145], and *Logical Theory Describing Financial Report*[146].

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[140] SAP, *Knowledge Graphs: A Dream of a Knowledge Network*, https://news.sap.com/2023/04/knowledge-graphs-dream-of-knowledge-network/
[141] *Puzzle Pieces of Digital Financial Reporting*, https://digitalfinancialreporting.blogspot.com/2023/11/puzzle-pieces-of-digital-financial.html
[142] *Puzzle Pieces of Digital Financial Reporting*, https://xbrlsite.azurewebsites.net/2023/Library/PuzzlePieces.jpg
[143] Puzzle Pieces of Digital Financial Reporting, https://digitalfinancialreporting.blogspot.com/2023/11/puzzle-pieces-of-digital-financial.html
[144] Charles Hoffman, CPA, *Essence of Accounting*, http://xbrlsite.azurewebsites.net/2020/Library/EssenceOfAccounting.pdf
[145] Charles Hoffman, CPA, *Financial Report Knowledge Graph*, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf
[146] Charles Hoffman, CPA, *Logical Theory Describing Financial Report*, http://xbrlsite.com/seattlemethod/LogicalTheoryDescribingFinancialReport_Terse.pdf

2.28.9. Model-based Reporting

Today, creating a financial report typically involves typing or copying/pasting information into a Microsoft Word document which understand nothing about financial reports. Model-based reporting involves representing a financial report as a model and then generating a machine-readable or human-readable version of the report and report model.

2.29. Assurance

In financial reporting there tend to be three main types of assurance services which are provided. Each provides a different level of scrutiny and independent third-party assurance:

- Compilation
- Review
- Audit

In addition, special cases of assurance can be provided in agreed upon procedures types of assurance engagements. Assurance services are typically provided by a certified public accountant (CPA) or chartered accountant (CA).

2.29.1. Compilation

A compilation is the most basic level of assurance. A compilation involves assembling a financial statement from an economic entity's accounting records. The accountant preparing a compilation does not offer any form of assurance on the accuracy of the financial statement which was created.

2.29.2. Review

A review engagement is more in-depth that a compilation. A review involves making certain inquires related to the creation of the financial statement and applying certain types of analytical procedures to determine if the statements are free from material errors or misstatements. Reviews do not tend to involve examination of internal controls or verifying information with third parties.

2.29.3. Audit

An audit engagement is the highest level of assurance services. An audit provides the highest level of assurance that the financial statements are free from material errors or misstatements. Audits include a comprehensive examination of the reporting economic entity's financial records, internal controls, verification using third parties, analytical procedures, and other such procedures to determine that a financial statement presents a true and fair view of the reporting economic entity's financial position and financial performance.

Auditors independently verify facts provided within a financial report.

The purpose of an audit is to provide an independent third-party opinion as to whether reported information about the financial condition and financial performance of an economic entity is being represented fairly by the information provided in a financial report, in all material respects. The audit is about the **independent third-party opinion** as to the fairness of that information. Financial reporting managers still need to represent information in their financial reports that reflects the true and

fair status and performance of an economic entity. They may not be independent of the economic entity, but the steps used in many cases by a reporting manager and an auditor are the same.

External financial reporting managers need to create true and fair representations of their financial information. The team that works with the external financial reporting manager needs to make sure the financial report is true and fair. Internal auditors that work for a company to make sure the external financial reporting manager is doing their job correctly need to make sure the information is true and fair. Finally, the CFO that signs off on the report needs to make sure the financial report information is true and fair.

The point here is that there are lots of people who care that the information contained in a financial report is represented appropriately, not just auditors. Many of the tasks and procedures auditors use are the same tasks and procedures that an external financial reporting manager should be using. Sure, some are different. But fundamentally, the objective is to make sure information is true and fair.

The *COSO Enterprise Risk Management Framework*[147] is a way of thinking about risk and internal accounting controls within an organization.

2.30. Analysis

Financial reports are created to provide information about the financial position and financial performance of regulators, investors, financial analysts, and other interested parties. Management of an economic entity is also interested in this information for the purposes of managing the economic entity. The level of detail might be different depending if a financial report is created for someone internal and someone external to the reporting economic entity.

[147] COSO Enterprise Risk Management Framework, http://xbrl.squarespace.com/journal/2021/4/13/coso-enterprise-risk-management-framework.html

Economic entities can use whatever organization they might choose for financial information that is consumed within that organization. However, when financial information is reported external to an economic entity and that report is required to be prepared using some specific financial reporting scheme then the rules of that financial reporting scheme must be applied to the external financial reports. External financial information can also be used for internal purposes but generally internal information is generally more detailed in nature.

Financial analysts and others create ratios[148] that are used to evaluate the information provided by an economy entity. An example of a few ratios include: working capital, debt to equity ratio, return on assets, return on equity, return on sales. Financial analysts created financial models such as the unlevered discounted cash flow model[149].

In summary, accountants need to:

- **Validate** that all information is accurate and properly classified
- **Analyze** that information to gain insights into what has happened, why it happened, what can be done to do things better next time
- **Simulate** different possible scenarios, looking into the future to figure out the best course of action

2.30.1. Financial Benchmarking

Economic entities and auditors tend to benchmark reported financial information against that economic entity's peers in order to search for reporting errors and to better understand reported financial information and financial trends. Because only summarized information tends to be available for peers, benchmarking tends to be at the financial report line item level.

2.30.2. Variance Analysis

Economic entities and auditors tend to analyze reported financial information against prior financial information for that economic entity to search for possible reporting errors and to better understand reported financial information and financial trends. Because all of this information is internal, variance analysis could be performed down to any level of detail.

In addition to variance from actual reported accounts, variance from budget(s) and/or any forecast(s) might also be performed if budgets and forecasts exist for an economic entity.

2.30.3. As Reported

Analysis can be provided using "as reported" financial information. As reported information refers to the actual financial information reported within a financial statement of an economic entity.

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[148] Ciaran Walsh, *Key Management Ratios*, https://www.amazon.com/Key-Management-Ratios-Financial-Times/dp/0273719092

[149] Charles Hoffman, CPA, *Representing Unlevered Discounted Cash Flow Model Using XBRL*, http://xbrl.squarespace.com/journal/2018/9/4/representing-unlevered-discounted-cash-flow-model-using-xbrl.html

2.30.4. Normalized

Analysis can be provided using "normalized" financial information. Normalized financial information can be useful when performing comparisons between different reporting economic entities that make use of different reporting styles. For example, if one reporting entity provides a single step income statement which does not report gross profit is compared to another reporting economic entity which provides a multi-step income statement which includes gross profit; normalization needs to take place in order to effectively compare the two reporting economic entities.

2.31. Topics

Topics are simply categories or groups or "families" into which disclosures can be organized.

2.32. Disclosures

Facts that flow from the double-entry accounting system to a report are not the only facts provided within a report such as an external financial report. A report also contains policies, disclosure notes, and other information that does not come from the double-entry accounting system. Commonly, that information is managed using spreadsheets, databases, and other approaches.

We described the notion of a fact ledger in the document *Introduction to the Fact Ledger*[150].

A fact ledger is a ledger in that it is used to record information. A fact ledger could be double-entry such as a general journal or a fact ledger can be single-entry and contain information that does not go through the double-entry accounting system.

The information that a fact ledger is used to record is facts. In my particular case I am interested in recording facts related to a financial report. But a fact ledger could be used to record a single fact, some set or sets of facts, or an entire database of information such as the complete set of all public company financial reports that have been submitted to a regulator such as the Securities and Exchange Commission (SEC) and placed into their EDGAR system[151]. Many different fact ledgers might be used in the process of creating a financial report.

A fact ledger is simply a standardized approach to managing the facts that make up financial report. An XBRL instance is an instantiation of a fact ledger using global standard syntax. But a collection of XBRL instances can also be a fact ledger.

Policies tend to be made up of mostly words which are not posted to a journal. Likewise, some disclosure notes likewise do not run through double-entry journals. But these policies and notes can be stored within a single-entry fact ledger. Disclosures[152], templates[153] that can be used to create disclosures, exemplars[154] or

[150] Charles Hoffman, CPA, and Andrew Noble, PNA, BBus, *Introduction to the Fact Ledger*, http://xbrlsite.azurewebsites.net/2018/Library/IntroductionToTheFactLedger.pdf
[151] XBRL Cloud, *EDGAR Dashboard*, https://edgardashboard.xbrlcloud.com/edgar-dashboard/
[152] US GAAP Disclosures, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Disclosures.html
[153] US GAAP Templates, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Templates.html

examples from other reports of the same sort of disclosure are all similar to small, machine-readable fact ledgers.

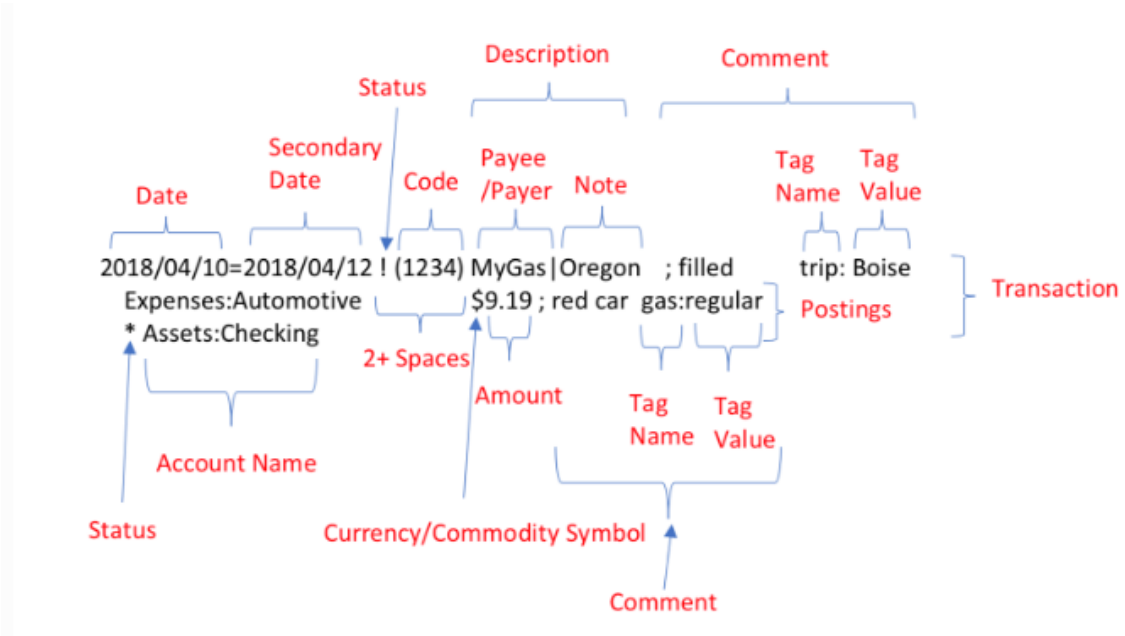
2.33. Metadata

Metadata[155] is simply data that provides information about other data. A chart of accounts is used to distinguish transactions that go through one account, say "Receivables", with those that go through some other account, say "Inventories". Commonly, more detail is necessary and so mechanisms exist to, say, distinguish one category of transactions related to "inventories" from another.

Different accounting systems have different mechanisms for categorizing transactions: subaccounts, additional database fields, tags, dimensions. Further, accounting systems might provide multiple mechanisms from which an accountant can choose and different accountants might make different choices. But essentially, logically the same thing is going on regardless of the means used to arrive at the fundamental objective: categorizing transactions.

XBRL also has a mechanism for distinguishing information details called XBRL Dimensions[156].

hledger and Ledger likewise have mechanisms for categorizing transactions. For example, hledger has the following mechanisms: code, description, comment, tag[157]. For example:



[154] US GAAP Examples, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Examples.html
[155] Wikipedia, *Metadata*, https://en.wikipedia.org/wiki/Metadata
[156] XBRL International, XBRL Dimensions 1.0, http://www.xbrl.org/specification/dimensions/rec-2012-01-25/dimensions-rec-2006-09-18+corrected-errata-2012-01-25-clean.html
[157] hledger, *Tags Tutorial*, https://hledger.org/tags-tutorial.html

Fundamentally, what is going on logically is that accounting information tends to be multidimensional[158]. When you work with transactions you can work at different levels of granularity. The lowest level of granularity is typically at the accounting transaction itself. The highest level of granularity are classifications that you might find on the primary financial statements. Then, you could have multiple levels in between.

Different types of transactions have different information that might be important. For example, a job costing system needs to track each job and a fixed assets management system tracks information about individual assets. Each accounting subsystem has information that is unique to that subsystem.

But what is common to all accounting subsystems is that it is sometimes critically important to track additional details. Call the piece of information you add a "subaccount" or "dimension" or "tag" or "field" or whatever you might come up with for a name. But fundamentally, what is going on is that transactions are being provided with different information and different subsystems need different information.

2.34. Provenance

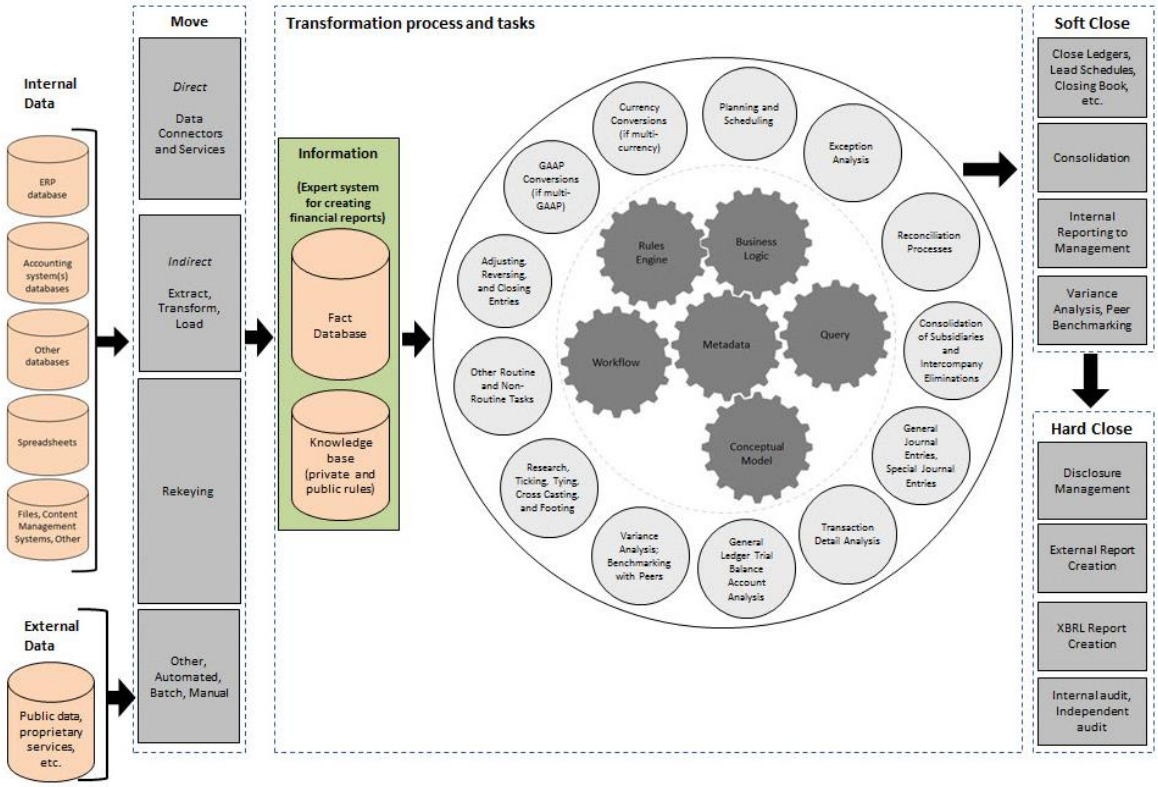
Being able to trace back to the origin of information and understand the chain of custody or who has access and could therefore manipulate information provides the possibility of establishing an audit trail.

Provenance is related to trust.

2.35. Complexity

The following graphic shows the processes and tasks involved in the creation of general purpose or special purpose financial report:

[158] YouTube.com, *Introduction to the Multidimensional Model for Professional Accountants*, https://youtu.be/A5AAruLUud4



Complexity enters this system in many ways including multiple currencies, multiple subsidiaries, multiple accounting information systems, multiple business activities, etc.

2.36. Quality

There are many different ways to define or think about quality. Engineer and statistician W. Edwards Deming[159] defined quality as "predictability," and called variance "the enemy of quality." To achieve an intended outcome, Deming thought it was important to plan for common-cause variation, which can be predicted, and special-cause variation, which cannot be predicted.

Harold F. Dodge, one of the principal architects of the science of statistical quality control said, "You cannot inspect quality into a product." In other words, once the inspection takes place, it's too late. Rather, data from the quality inspection needs to be utilized to continually improve the process.

Businessman Philip B. Crosby, who developed the concept of Zero Defects while working as senior quality engineer at aircraft manufacturer The Martin Company, defined quality as "a conformance to requirements." He warned against the high cost of nonconformance and said that the desired performance standard of zero defects could only be achieved through the proper management system.

[159] YouTube.com, *A Theory of a System for Educators and Managers*, https://www.youtube.com/watch?v=2MJ3lGJ4OFo

Management consultant Joseph Juran, who focused on management training and the human element of quality control for a variety of businesses, stated that quality is "a fitness for use."

2.37. Controlling Quality

Lean Six Sigma[160] is a discipline that combines the problem-solving methodologies and quality enhancement techniques of Six Sigma[161] with the process improvement tools and efficiency concepts of Lean Manufacturing[162]. Born in the manufacturing sector, Lean Six Sigma[163] works to produce products and services in a way that meets consumer demand without creating wasted time, money and resources.

Specifically, Lean is 'the purposeful elimination of wasteful activities.' It focuses on making process throughout your company faster, which effects production over a period of time. Six Sigma works to develop a measurable process that is nearly flawless in terms of defects, while improving quality and removing as much variation as possible from the system.

Manual approaches, automated approaches, or a combination of both manual and automated approaches can be used to control quality.

2.38. Best Practice

A **best practice** is a method or technique that has been generally accepted as superior to any alternatives because it produces results that are superior to those achieved by other means or because it has become a standard way of doing things, e.g., a standard way of complying with legal or ethical requirements.

2.39. Digital Distributed Ledger

Explaining digital distributed ledgers in any detail is beyond the scope of this document; I would refer you to *Comprehensive Introduction to Digital Distributed Ledgers*[164]. There are a lot of details that still need to be worked out but digital distributed ledgers appear promising. That said, we do want to introduce the idea.

A digital distributed ledger[165] is an indestructible and un-editable decentralized computer record, or ledger. A digital distributed ledger provides a full and complete history of transactions in that ledger. Ledgers can be as public and open or private and limited as the use case demands. Ledgers can be permissioned or permission-less in determining who can add new transactions. Different approaches can be used to determine how new transactions are authorized (proof-of-stake, proof-of-work,

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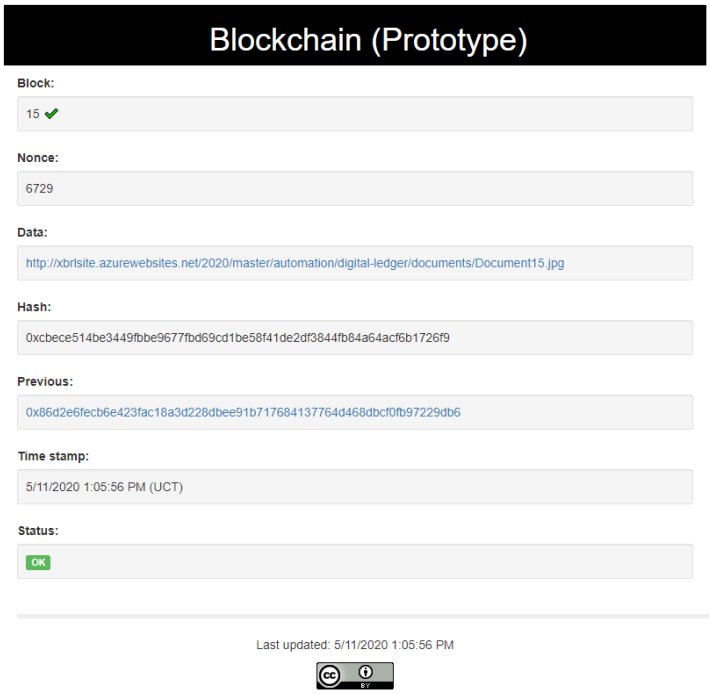
[160] Wikipedia, *Lean Six Sigma*, https://en.wikipedia.org/wiki/Lean_Six_Sigma
[161] Wikipedia, *Six Sigma*, https://en.wikipedia.org/wiki/Six_Sigma
[162] Wikipedia, *Lean Manufacturing*, https://en.wikipedia.org/wiki/Lean_manufacturing
[163] Charles Hoffman, CPA and Rene van Egmond, *Comprehensive Introduction to Lean Six Sigma*, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part01_Chapter02.72_LeanSixSigma.pdf
[164] Charles Hoffman, CPA, *Comprehensive Introduction to Digital Distributed Ledgers*, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part01_Chapter02.71_DistributedLedgers.pdf
[165] Wikipedia, *Distributed Ledger*, https://en.wikipedia.org/wiki/Distributed_ledger

consensus, identity mechanisms) before they can add new information to the ledger. Ledgers can be interlinked with one or more other ledgers.

The following is a summary of the characteristics of a digital distributed ledger:

- No hackers can corrupt information because there is no centralized version; there are many versions and they all must agree
- Immutable (unchangeable, secure, set in stone)
- No centralized administrator/authority owns the system
- Entries into ledger are "notarized" (similar to idea of notary public)
- Public or private; permissioned or permission-less
- Machine readable
- Stand alone or interlinked with other ledgers

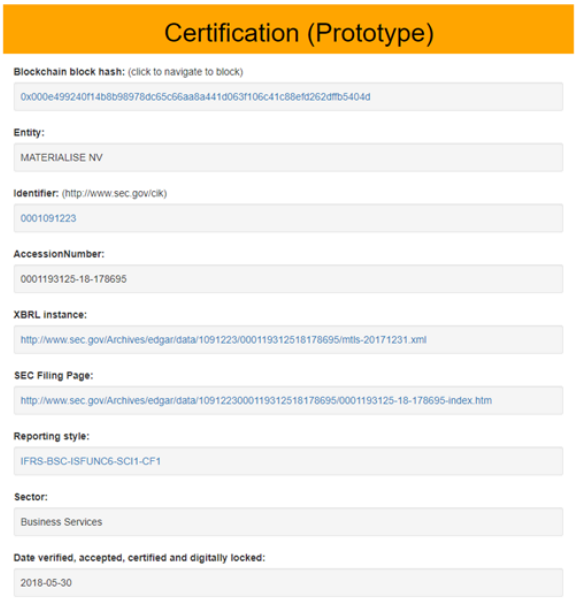
The following is a prototype digital distributed ledger created so that you can get the feel of such ledgers[166]:



This[167] is a second digital distributed ledger example.

[166] Digital Distributed Ledger Prototype, http://xbrlsite.azurewebsites.net/2020/master/automation/digital-ledger/blocks/0xcbece514be3449fbbe9677fbd69cd1be58f41de2df3844fb84a64acf6b1726f9.html

[167] Second digital distributed ledger prototype, http://xbrlsite-app.azurewebsites.net/io/certification/0x000e499240f14b8b98978dc65c66aa8a441d063f106c41c88efd262dffb5404d.html



2.40. Triple Entry Accounting System

The idea of triple entry accounting was first introduced by Yuji Ijiri in 1989 in his book *Momentum Accounting & Triple-Entry Bookkeeping*[168]. In 2005, cryptographer Ian Grigg provided a more well-known example of a triple-entry accounting system, in a paper, *Triple Entry Accounting*[169]. Some are saying that triple-entry accounting is the most important invention of the last 500 years[170].

With triple entry accounting, both parties to a transaction would complete a transaction and simultaneously record information about that transaction in a shared ledger such as a digital distributed ledger. Once that happens, it's necessary to ensure that that information about that transaction can't be changed.

2.41. Repeatable Method

I have published a number of documents trying to show and explain the process of creating a financial report. This is a summary of information from those documents and what I was trying to achieve. Right now, I can say that I do have a method for creating high-quality XBRL-based digital financial reports. I cannot say that I have adequately documented this best practices-based method yet.

What I am trying to show in the document *General Ledger Trial Balance to External Financial Report*[171], is a basic example of taking the information from a general journal to a general ledger and then ultimately to a financial report using XBRL. The

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[168] Yuji Ijiri, *Momentum Accounting & Triple-Entry Bookkeeping*, American Accounting Association, https://www.goodreads.com/book/show/15067963-momentum-accounting-triple-entry-bookkeeping

[169] Ian Grigg, *Triple Entry Accounting*, http://iang.org/papers/triple_entry.html

[170] Daniel Jeffries, *Why Everyone Missed the Most Important Invention in the Last 500 Years*, https://hackernoon.com/why-everyone-missed-the-most-important-invention-in-the-last-500-years-c90b0151c169

[171] Charles Hoffman, CPA, *General Ledger Trial Balance to External Financial Report*, http://xbrlsite.azurewebsites.net/2018/RoboticFinance/TrialBalanceToReport.pdf

beginning of the process is the accounting system which summarized the information, the end of the process is a human readable and machine readable financial report.

What I was trying to show in the document *INTELLIGENT DIGITAL FINANCIAL REPORTING – PART 4: EXAMPLES AND SAMPLES – COMPREHENSIVE EXAMPLE*[172], is a much more complex financial report which was created using the same techniques as the basic example. Not that this document has several "forests" or disjointed unions of trees meaning that not all the information in this financial report is run through the general ledger trial balance.

What I am trying to show in the blog post *Representing Unlevered Discounted Cash Flow Model Using XBRL*[173], is both how information from a financial report is used by financial analysts to analyze economic entities reporting information and that such models can be created using techniques similar to how the financial reports themselves are created.

What I am trying to show in the document *Introducing the Fact Ledger*[174], is that intermediate documents or ledgers can be used to summarize information that is used within this process.

What I am trying to show in the document *Blueprint for Creating Zero-Defect XBRL-based Digital Financial Reports*[175]; is how business rules can be used to automate many of the tasks related to moving information from one step to another, verifying that information is correct and otherwise of high quality so that these processes can be reliable.

What we are trying to show in the document *Putting the Expertise into an XBRL-based Knowledge Based System for Creating Financial Reports*[176], are general ideas related to how patterns can be leveraged when creating software that is useful in creating XBRL-based financial reports.

Finally, what I tried to show in the document *Guide to Building an Expert System for Creating Financial Reports*[177], are specific techniques we used to create Pesseract[178] which is a working proof of concept which we used to prototype and test the ideas in

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[172] Charles Hoffman, CPA and Rene van Egmond, *INTELLIGENT DIGITAL FINANCIAL REPORTING – PART 4: EXAMPLES AND SAMPLES – COMPREHENSIVE EXAMPLE*, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part04_Chapter07.5_ComprehensiveExample.pdf

[173] Charles Hoffman, *Representing Unlevered Discounted Cash Flow Model Using XBRL*, http://xbrl.squarespace.com/journal/2018/9/4/representing-unlevered-discounted-cash-flow-model-using-xbrl.html

[174] Charles Hoffman and Andrew Noble, *Introducing the Fact Ledger*, http://xbrlsite.azurewebsites.net/2018/Library/IntroductionToTheFactLedger.pdf

[175] Charles Hoffman, *Blueprint for Creating Zero-Defect XBRL-based Digital Financial Reports*, http://xbrlsite.azurewebsites.net/2017/Library/BlueprintForZeroDefectDigitalFinancialReports.pdf

[176] Charles Hoffman and Hamed Mousavi, *Putting the Expertise into an XBRL-based Knowledge Based System for Creating Financial Reports*, http://pesseract.azurewebsites.net/PuttingTheExpertiseIntoKnowledgeBasedSystem.pdf

[177] Charles Hoffman, *Guide to Building an Expert System for Creating Financial Reports*, http://xbrlsite.azurewebsites.net/2018/Library/GuideToBuildingAnExpertSystemForCreatingFinancialReports.pdf

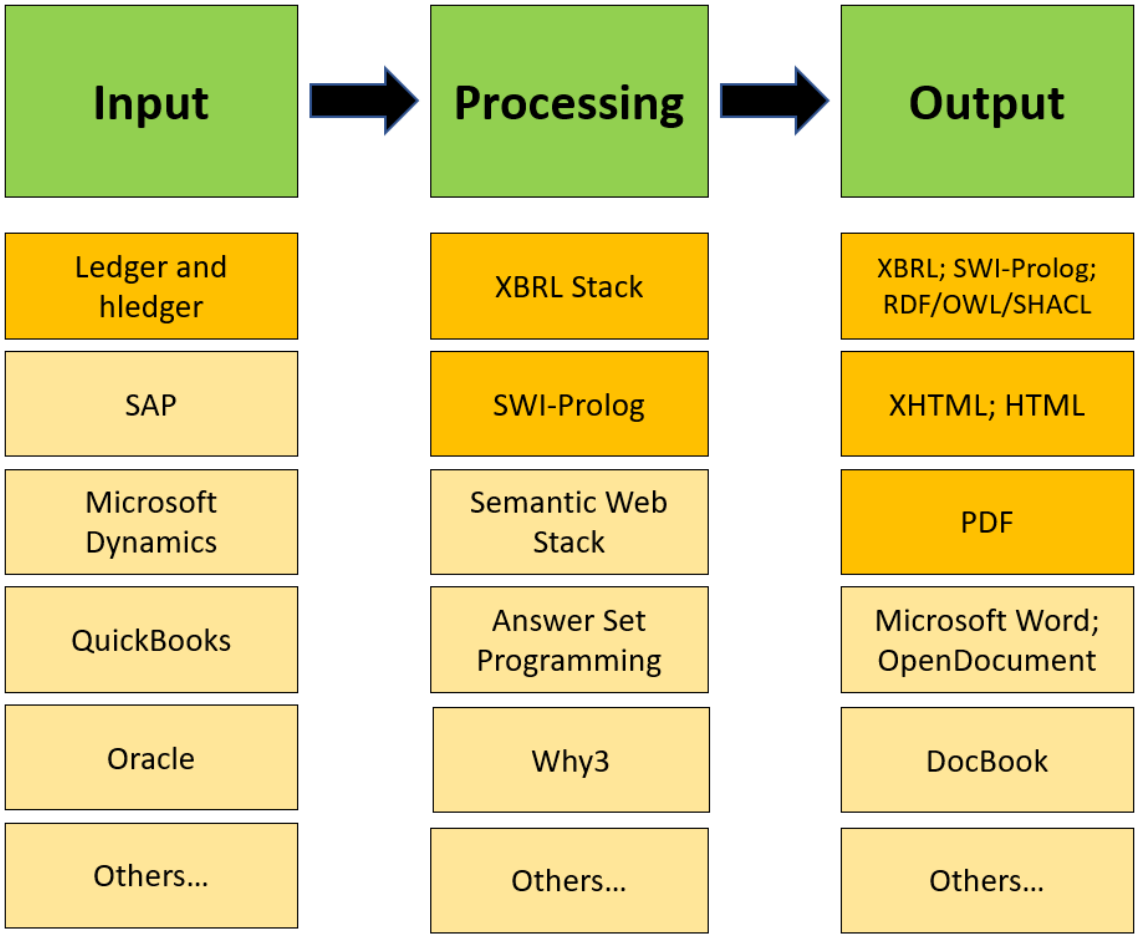
[178] Pesseract, http://pesseract.azurewebsites.net/

this document. The application can be downloaded and used to better understand these ideas.

My next step is to turn all of this information into a documented method that is easy to understand.

2.42. Ecosystem

Imagine an ecosystem that is as elegant as an iPhone for accounting, reporting, auditing, and analysis. Imagine if standard technical syntaxes existed and you could convert bidirectionally from one syntax back to some other syntax. Imagine if the logic of accounting, reporting, auditing, and analysis was agreed to by the members of the supply chain. Software vendors and other stakeholders could plug into this digital ecosystem and add value. Imagine if standard output formats were agreed to. Imagine something like this:



Imagine if ISO and OMG standards were leveraged similar to how the ISO standard shipping container, the Universal Product Code is leveraged in retail, or MPEG formats for movies.

Youtube.com does not support just one single technical format, it supports all of the follow following formats: MOV, MPEG4, AVI, WMV, MPEG PS, FLV, 3GPP and WebM.

Multiple technical formats are a reality.

This ecosystem already exists to a degree. The darker orange color exists and works today. The lighter color orange does not yet work. Piece-by-piece, this will ultimately be put together.

2.43. Debate about Debits/Credits and Double Entry

There is a debate about whether the traditional notions of "debits and credits" or "double entry" ledgers is necessary. Both of these debates are really unnecessary.

It has been shown that one can convert from a "debit/credit" scheme to a "+/-" scheme for values. (Although, I am not sure if you can convert from a "+/-" scheme to a "debit/credit" scheme.

Double-entry relates more to the segregation of duties and internal controls as opposed to debits and credits.

The answer to both of these questions will reveal themselves with the creation of software applications that will, or will not, get the necessary tasks and processes done. If they prove to be necessary; leave them. If they prove to be unnecessary; remove them.

3. Informatics Literacy

There is no one formal definition of informatics as far as I can tell. This is one definition that I synthesized from other definitions that I like:

Informatics[179] relates to the intersection of information, people, and technology and the practical application of computational systems; understanding how people will "live" in the digital realm within some specific area of knowledge that makes sense to users of that technology.

- Informatics is the conscious management of information, knowledge, and accumulated knowledge
- Management of information includes information creation, editing, use, storage, exchange, and removal (CRUD)
- Informatics spans the knowledge accumulation process of an
    - individual member (learning)
    - organization (institutionalized knowledge)
    - area of knowledge (professional knowledge; subject matter)
- Informatics has theories, principles, frameworks, and strategies that can be applied to solve information management problems
- Informatics is about harnessing the power and possibility of digital technology to transform data and information into knowledge that people use every day
- Informatics is about understanding how people will "live" in the digital realm with an elegance of design that makes sense to users of a particular technology
- Informatics is about delivering the best user experience possible

[179] Wikipedia, Informatics, https://en.wikipedia.org/wiki/Informatics

Analogy to a chef: Similar to how a chef transforms a recipe using kitchen equipment into an unforgettable meal; informatics transforms the use of information and knowledge into a successful experience.

Analogy to architect: Similar to an architect that transforms a building into a livable space by placing doors, windows, and utilities with functionality and ease; informatics improves "digital livability".

Key terms related to informatics include:

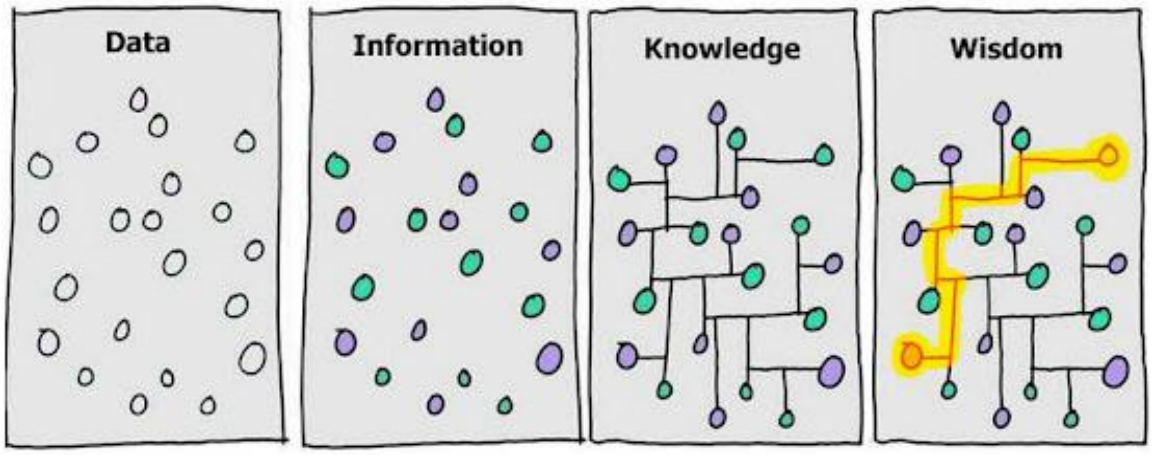
- DIKW Model
- Information
- Knowledge
- Common knowledge
- Accumulated knowledge
- Area of Knowledge
- Understandability
- Information Exchange Standards
- Knowledge Representation and Reasoning
- Knowledge Commitment
- Knowledge Products
- Mediums of Exchange
- Gamification
- Digital Distributed Ledger
- Process
- Smart Systems

We are in the information age[180]. Some call this the third industrial revolution, others say it is the fourth industrial revolution. Ditch the "data" perspective!

3.1. DIKW Model

The DIKW Model explains the important difference between data, information, knowledge, and wisdom:

[180] Wikipedia, *Information Age*, https://en.wikipedia.org/wiki/Information_Age



- ***Data***: raw, unprocessed, uninterpreted items; tends to be understandable only in one specific local context which tends to be assumed
- ***Information***: data that has been processed and organized to some extent and provided in some explicit context
- ***Knowledge***: refined and actionable information that has been further processed, organized making the information super-useful
- ***Wisdom***: use of data, information, knowledge and insight in making decisions or taking action; insight and wisdom come from applying knowledge to some specific situation.

Insight is the process of turning knowledge into wisdom.

Knowledge products offer new possibilities completely new types of products and for entirely new business models[181].

3.2. Information

Information has a formal definition. *Information* is something that you do not know and which you cannot derive from your existing accumulated knowledge. Information relates to facts about a subject matter in a context. Information is a "surprise"; information causes you to either change your mind and accept the information or not change your mind and reject the information. Information is relative meaning that information has context. Someone can already know something (knowledge) that is unknown of for others (information).

- Facts carry information.
- Information content of a fact is a true proposition.
- Information a fact carries is relative to a context.
- Information can be stored and transmitted in a variety of physical, technical forms.

[181] *Knowledge Products Offer New Business Models*, https://digitalfinancialreporting.blogspot.com/2024/02/a-new-business-model-is-emerging-which.html

3.3. Knowledge

Knowledge is a form of familiarity with information from some specific field or area of knowledge. Knowledge is often understood to be awareness of facts, having learned skills, or having gained experience using the things and the state of affairs (situations, changes in a state of affairs) within some area of knowledge.

Knowledge is not "bag" of random facts that an individual, institution, or area of knowledge knows about. Knowledge is a structured, self-reflecting, verifiable, provable system.

Knowledge can be grouped into two categories:

- ***Transferable knowledge:*** objective; independent from human interpretation and emotions; goal is to make human minds uniform, reliable, replaceable; playing a role as perfectly as possible rather than "showing off with risky tricks"
- ***Non-transferable knowledge:*** subjective; involves emotions and personal preference; affects every individual differently therefore changes how knowledge is processed

Information systems only work with transferable knowledge.

3.4. Common Knowledge

Common knowledge is a type or category of knowledge and refers to information that the typical person with skill and experience within a specific area of knowledge would accept as correct.

What may be common knowledge of an area of knowledge in one local might be different that the common knowledge in some different local.

3.5. Accumulated Knowledge

Accumulated knowledge is information collected over time. Accumulated knowledge is total knowledge collected by an individual, an institution, an area of knowledge, or a society.

An individual can handle only a relatively small portion/part of this total accumulated knowledge of some full area of knowledge. However, tools can be used to increase the amount of information an individual can handle.

Experience and education within an area of knowledge introduces new information to that total accumulated knowledge. That new information is merged and added to accumulated knowledge of the specific area of knowledge.

3.6. Area of Knowledge

An area of knowledge is a highly organized socially constructed aggregation of shared knowledge for a distinct subject matter. An area of knowledge has a specialized insider vocabulary, underlying assumptions (axioms, theorems, constraints), and persistent open questions that have not necessarily been resolved (i.e. flexibility is necessary). An area of knowledge can be:

- ***Kind area of knowledge***: clear rules, lots of patterns, lots of rules, repetitive patterns, and unchanging tasks.

- ***Wicked area of knowledge***: obscure data, few or no rules, constant change, and abstract ideas.

Other terms for area of knowledge include "knowledge domain", "universe of discourse", "subject matter", "domain of understanding", or simply "domain".

The complexity patterns of an area of knowledge can be explained by the Cynefin Framework[182]. The transferable knowledge of an area of knowledge can be categorized into the following groups:

- ***Best practices***: things that tend to be obvious even to people outside an area of knowledge. There tends to be only one way to do something which makes sense.
- ***Good practices***: things that are a bit more complicated but the subject matter experts within an area of knowledge that have skills and experience tend to agree on these practices. Different groups can use different preferred good practice approaches as a matter of policies.
- ***Emergent practices***: things that are even more complex and subject matter experts within an area of knowledge tend to disagree with one another as to what the good practices are which leads to multiple different views, each which is reasonable based on the principles of an area of knowledge and the logical patterns of the situation
- ***Novel practice***: this is similar to emergent practices except that there are no identifiable logical patterns of the situation and no identifiable principles that can be applied; but logical answers can be figured out but the clustering of answers is more spread out, not as tight.

Disorder is not transferable knowledge. Norms of an area of knowledge, in the form of best, good, emergent, and novel practices is transferable knowledge; but they each works a little differently.

3.7. Understandability

Understandability is the ability to make use of information and knowledge. There are levels of information/knowledge understandability[183]. The following is a summary of those levels:

- ***Presentation level sharing***: Understandable by humans, not understandable by machines, no low-level model, no high-level model.
- ***Data level sharing***: Not understandable by humans, understandable by machines, local or no low-level model, no high-level model.
- ***Meaning level sharing***: Not understandable by humans, understandable by machines, global oriented low-level model, no high-level model. (Can be understandable to motivated, technical oriented humans).
- ***Knowledge level sharing with machine understandability***: Understandable by humans, understandable by machines, global oriented

[182] YouTube.com, *Complexity, Cynefin, and Agile*, https://www.youtube.com/watch?v=-F4enP8oBFM
[183] Understandability, https://digitalfinancialreporting.blogspot.com/2024/04/understandability.html

low-level model, global oriented high-level model. (Can be understandable to business oriented humans).

When a human or a machine understands information and knowledge then that information or knowledge can be used by a process or system.

3.8. Knowledge Acquisition

There are no short cuts. No one really disputes the need for models and a "thick layer of metadata" to get a computer to perform work. What is disputed is the best way to get that thick layer of metadata and those models. Machine learning works best if you already have a thick layer of metadata, that is the training data that machine learning needs to work.

There tends to be three approaches to acquiring knowledge:

- ***Handcrafted knowledge***: Skilled and experienced subject matter experts for some area of knowledge create/construct the knowledge representation. This approach can be costly and take time, but it also yields the highest result if done correctly.
- ***Statistical learning***: Also referred to as machine learning, of which there are various forms, but all approaches are based on probability and statistics. While this approach can cost less, the quality can be significantly lower. This tends to be referred to as unsupervised learning.
- ***Combining handcrafted knowledge approach and statistical learning approach***: Combining both approaches, called supervised statistical learning, is where humans and machines work together to achieve the highest quality result with the least expense and time being involved.

3.9. Knowledge Representation and Reasoning

Knowledge representation and reasoning (KRR)[184] is about converting information from an area of knowledge into machine understandable form and then enabling a machine such as a computer using software to process that information in a manner that is as good as a human could have performed that task/process or even better than a human could have performed that task/process (e.g. beyond-human capabilities). Knowledge must be acquired, represented, and then some reasoning process performed.

The following approaches can be use to represent knowledge beginning with the least expressive approach and ending with the most expressive approach:

- Name authority (dictionary)
- Thesaurus
- Taxonomy
- Ontology
- Theory

[184] Knowledge Representation and Reasoning (KRR), https://digitalfinancialreporting.blogspot.com/2024/04/knowledge-representation-and-reasoning.html

The following are the reasoning approaches that can be used to reason against some set of knowledge:

- Deductive reasoning
- Inductive reasoning
- Abductive reasoning

3.10. Knowledge Commitment

The notion of knowledge commitment[185] is similar to the notion of ontological commitment. In simple terms, when you make an ontological commitment, you're essentially saying "I agree that these things exist in the way we have defined them in our shared understanding and I will use these definitions, associations and rules consistently when we talk about those things." This shared understanding enables all sorts of possibilities. When the stakeholders of a system agree, make a knowledge commitment, achieving goals and objectives using automated information systems becomes possible.

3.11. Knowledge Products

A logical twin[186] or logical digital twin is effectively a professional quality knowledge graph. A logical twin is a deliberate innovation that is intended to be safe, practical, and consistently reliable. A logical twin can be thought of as the packaging of information to create a product or service.

A knowledge product[187] is refined and actionable information that has been processed, organized, and/or structured in some way or put into practice in some way making the information super-useful. The information is ready to use. The knowledge is derived from expertise, research, lessons learned. Knowledge products allow the user of the knowledge product to make informed decisions or better decisions.

- **Data product/service**: a reusable raw and unprocessed data asset, engineered to deliver a trusted dataset to a user for a specific purpose; they are for specific use and not designed for reuse
- **Information product/service**: organized, processed, and perhaps even interpreted data which provides context and meaning; they give you information
- **Knowledge product/service**: refined and actionable information that has been processed, organized, and/or structured in some way or put into practice in some way making the information super-useful; they tell you something you want to know using information

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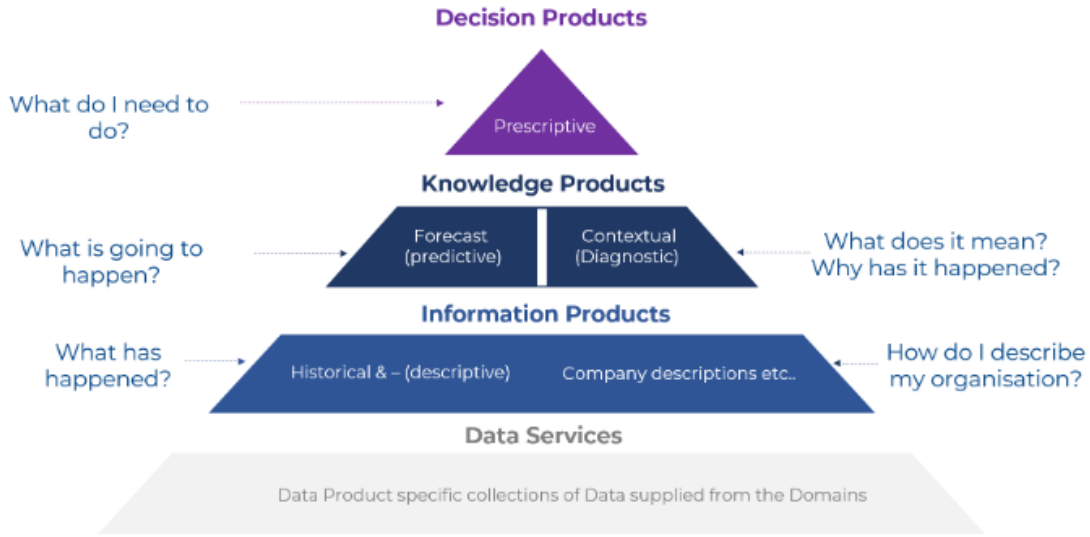
[185] Knowledge Commitment, https://digitalfinancialreporting.blogspot.com/2023/12/knowledge-graph-commitment.html
[186] Logical Digital Twin, http://www.xbrlsite.com/mastering/Part02_Chapter05.A0_LogicalDigitalTwin.pdf
[187] Knowledge Products offer New Business Models, https://digitalfinancialreporting.blogspot.com/2024/02/a-new-business-model-is-emerging-which.html

- **Decision product/service:** tell a business professional what they need to do or actually execute an action making use of the information of the decision product; they tell you what to do or take action on your behalf

Data, information, knowledge, and decision products/services can be viewed as a pyramid[188]:



These products and services are accessed programmatically using algorithms. They tend to be accessed from trustworthy sources, are provided using standard formats, are self-describing, and interoperable.

3.12. Information Design Patterns

Information design is a discipline concerned with the displaying information in ways that support the effective and efficient understanding of that information by the intended audience and in the expected context.

Information design patterns are logic and principle-driven guidelines convoyed by practical examples of how the patterns have been implemented in real life.

Consider the financial disclosure as an example. The work of creating a disclosure is tedious; yet at the same time there are very serious consequences from errors. The current conventional disclosure review process is labor intensive, prone to human error, time consuming, and costly. But, tremendous, almost magical, benefits from such self-enforcing, machine-readable digital representations of disclosures.

Rather than drafting a disclosure; think rather of designing a disclosure where strategic choices about the drivers and goals of collaboration merge with the business and financial knowledge and the maximization of success and minimization of risks all centered around a software user interface that enables financial disclosures to be constructed, reviewed, and evaluated better, faster, and cheaper than you would have otherwise believed possible.

Magic? No. Good information design.

[188] Data Product Pyramid, https://dataception.com/blogs/Data-Product-Pyramid/Data-Product-Pyramid.html

Software-aided disclosure specification, construction, verification/review, and extraction aided by Lean Six Sigma techniques offers very dramatic improvements in efficiencies when used by those humans skilled in some area of knowledge creating or otherwise working with such disclosures. After all, software is only as good as the operator of that software.

Disclosure design is not only about selecting the right numbers, the right context, the right words and clauses. It is also about making sure that the message that you desire to communicate is understood. It is about enhancing disclosure clarity and ease of use.

In a human-computer system where the system is composed of people, computers, and financial information; we need to ensure that the people do not become the weak link of that system. Computers can assist in the processes of planning, constructing, testing, reviewing, and analyzing disclosure information and other such artifacts of accountancy.

The backbone of a disclosure is rarely drafted completely from scratch. Rather, a disclosure tends to be copied from some other prior use of a similar disclosure, reused as templates. Libraries of properly worded clauses are also possible. Being digital, this information can be organized, sorted, searched.

Design patterns are reusable models of solutions to commonly occurring disclosure problems. Commonly occurring disclosure design patterns can alleviate the challenges, the tedium, of creating these common disclosures. That frees up humans to focus on less common and more challenging financial disclosure problems.

3.13. Oracle Machine

An oracle[189] is a person or agency, like a software application, considered to provide wise, insightful, useful information or counsel or perhaps useful simulations or predictions. For example, a Certified Public Accountant (CPA) provides accounting and business related advice on specific topics; a CPA is an example of an oracle: a trusted business adviser.

An oracle machine[190] can be thought of as a Turing machine connected to an oracle of machine-readable information and rules. The oracle, in this context, is a software application capable of solving some computational problem (logical, mathematical), which for example may be a construction problem, a decision problem, or a function problem.

Imagine an accountancy oracle machine created using global standards[191].

3.14. Mediums of Exchange

New mediums of exchange are available. A logical digital twin of a financial report is a knowledge graph that can be used to exchange information reliably and therefore effectively:

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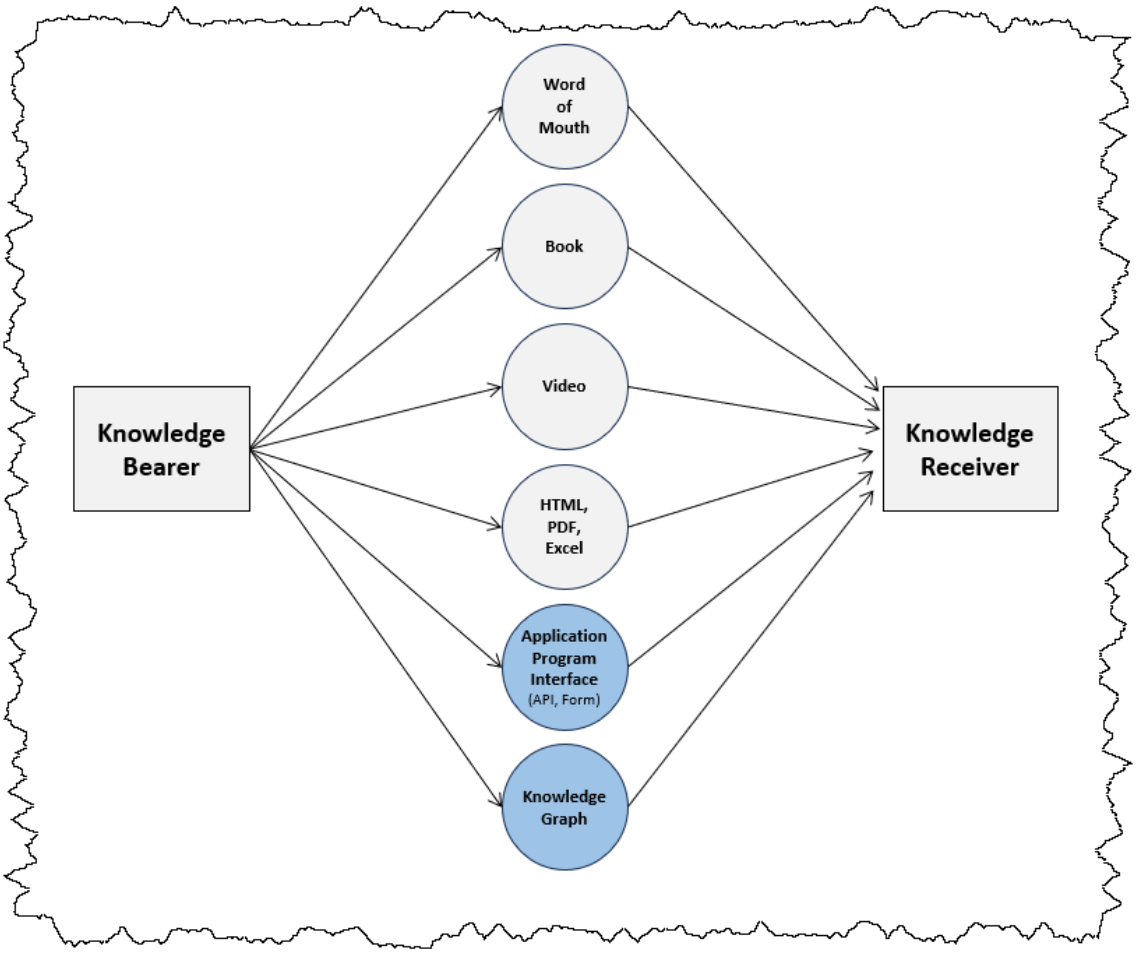
[189] Wikipedia, *Oracle*, https://en.wikipedia.org/wiki/Oracle
[190] Wikipedia, Oracle Machine, https://en.wikipedia.org/wiki/Oracle_machine
[191] Global Standards based Accounting and Reporting Oracle Machine Prototype, https://digitalfinancialreporting.blogspot.com/2023/11/global-standards-based-accounting-and.html



XBRL is an extra fancy type of knowledge graph[192]. XBRL enables the creation of provably high-quality logic oriented "bricks" or "Legos" of information[193]. Those bricks/Legos can be used to create even more complex representations of information.

3.15. Information Exchange Standards

Standards can be created to minimize the idiosyncrasies of *syntax* (e.g. differences in physical technical format preferred by different information technology professionals) and semantics (e.g. differences in conveying meaning by business professionals). Use of standard information exchange medias makes things easier. In order to make use of a knowledge media effectively, the following three conditions must be satisfied:

[192] XBRL is an Extra Fancy Type of Knowledge Graph, https://digitalfinancialreporting.blogspot.com/2024/05/xbrl-is-extra-fancy-knowledge-graph.html
[193] Knowledge Bricks and the Story of the Three Little Pigs, https://digitalfinancialreporting.blogspot.com/2024/04/knowledge-bricks-and-story-of-three.html

1. ***Easy for knowledge bearer to represent information***: The effort and difficulty required for the knowledge bearer to successfully formulate the knowledge in the medium must be as low as possible.
2. ***Clear, consistent meaning***: The meaning conveyed by the knowledge bearer to the knowledge receiver must be clear and easily followed by human beings and be consistent between different software applications.
3. ***High-quality information representation***: The form in which the knowledge is represented to the receiver must be as good as possible. The quality must be high whether the knowledge receiver is a human-being or an automated machine-based process.

3.16. Gamification

Gamification[194] is the strategic attempt to enhance information systems, services, organization's and activities in order to create similar experiences to those experienced when playing games in order to motivate and engage users.

3.17. Digital Distributed Ledger

A digital distributed ledger[195] is an indestructible and un-editable decentralized computer record, or ledger. A digital distributed ledger provides a full and complete history of transactions in that ledger. Ledgers can be as public and open or private and limited as the use case demands. Ledgers can be permissioned or permission less in determining who can add new transactions. Different approaches can be used to determine how new transactions are authorized (proof-of-stake, proof-of-work, consensus, identity mechanisms) before they can add new information to the ledger. Ledgers can be interlinked with one or more other ledgers. Effectively, a digital distributed ledger can be thought of as a database where items might be marked as deleted but no information is every really removed from the database.

3.18. Process

A **process** is a set of steps or actions that when consistently followed leads from some starting point to the completion of some objective. A process can involve multiple workflows. A process tends to repeat.

A **project** is a type of process that does not repeat. All projects are processes; but not all processes are projects. The difference between a project and a process is how often you perform some set of steps or actions. The more often a set of steps or actions is performed; the more benefit there is to spending time to gain control over a process.

Workflow is a sequenced set of processes; it describes the flow of inputs to outputs as a result of a process.

Making a process efficient is different than making a project efficient. Project managers are experts in handing processes that do not repeat.

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[194] Wikipedia, *Gamification*, https://en.wikipedia.org/wiki/Gamification
[195] *Digital Distributed Ledger*, http://www.xbrlsite.com/mastering/Part01_Chapter02.J_DistributedLedgers.pdf

Finding creative solutions to a problem adds value. Making processes more efficient and less costly helps improve the quality of service.

Efficiency and productivity benefits everyone. Increasing efficiency or productivity without maintaining or increasing process quality is useless.

Professionals such as accountants often tremble when someone discusses standardizing accounting/auditing processes. Perhaps they have nightmares about accounting/audit services "production lines" where they perform a routine step akin to a worker on an automobile assembly line. Perhaps these professionals see standardization as robbing them of "creativity" or from the exercise of "professional judgement". Perhaps they see their services more like artwork which sets them apart and which defines their approach to solving client problems.

But standardization does not actually inhibit creativity; standardization actually enhances creativity.

Clients want accounting and audit professionals to deliver creative solutions to their problems; they know that creativity adds value, and clients are willing to pay for that value. But clients also want accountants and auditors who are efficient when it comes to executing the creation of those solutions. Inefficient execution of the steps and actions of a process or project does not add value. Clients do not want to, and should not have to, pay for that kind of inefficiency.

In the end, inefficiency robs the accounting or audit professional providing consulting services of the time they could have used to provide real value; of time they could have been putting their minds to work assembling a creative solution.

Standardization of processes takes inefficiency and cost out of professional services and frees up time for those professionals to perform more creative and value adding forms of work. Standardization of processes also reduces the cost of training new professionals.

When a process is not repeatable and therefore a project; then accountants and auditors need to act as project managers. But the typical accountant or auditor does not have training in project management which is a complex discipline. As a result, most professional services projects are not well managed and/or accountants or auditors waste client resources muddling through the management of a project.

Machines can help accounting and audit professionals improves processes. Take the example of how a machine like a calculator improves the process of verifying that a set of numbers foots and cross casts correctly. Computers can help us improve processes. Computers can augment the skills and experience of an accountant or auditor.

Process control techniques such as Six Sigma[196] and Lean Thinking[197], or combined as Lean Six Sigma[198], are techniques, principles, frameworks, strategies for improving efficiency, enhancing productivity, and managing quality.

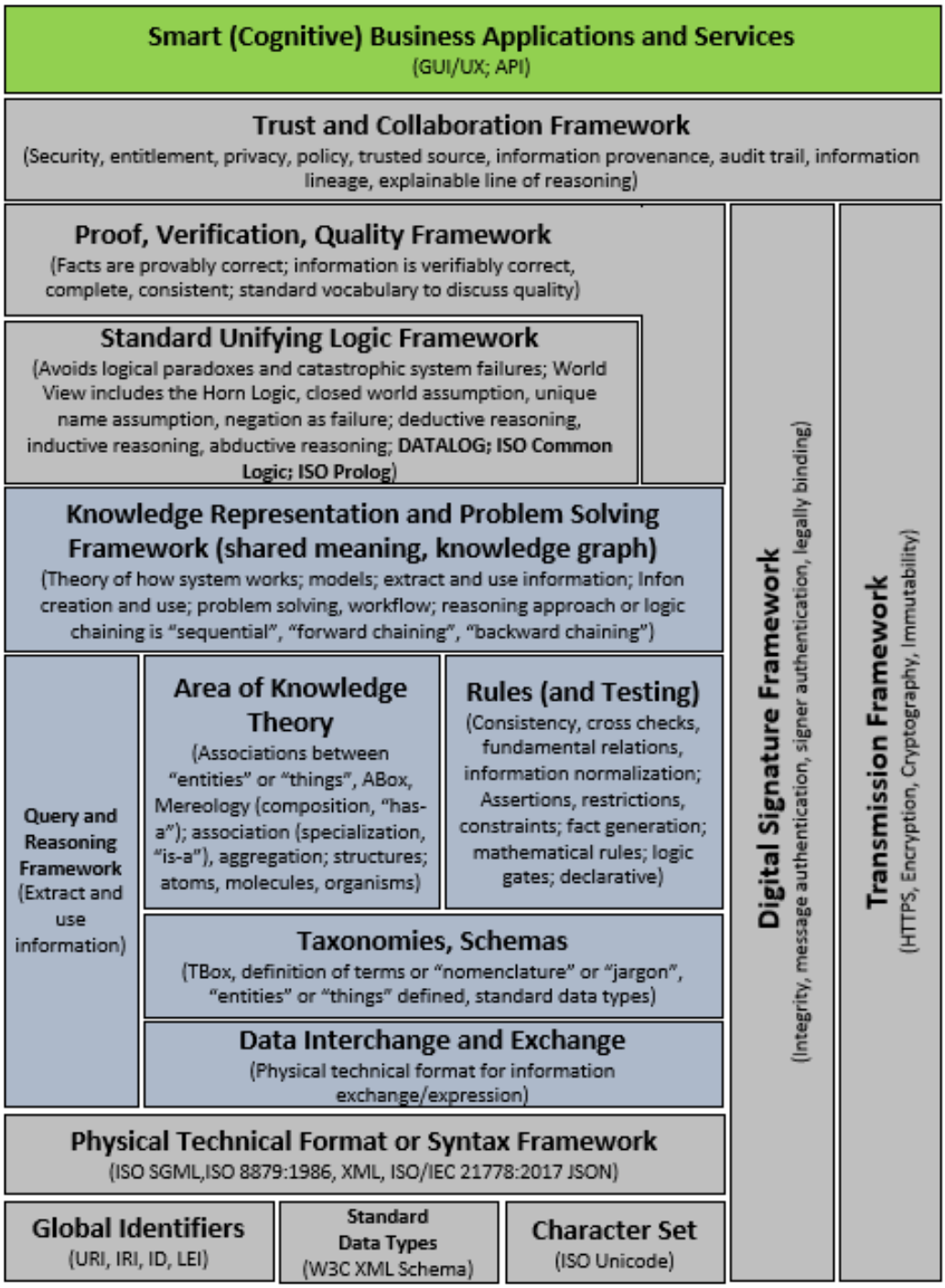
[196] Wikipedia, *Six Sigma*, https://en.wikipedia.org/wiki/Six_Sigma
[197] Wikipedia, *Lean Thinking*, https://en.wikipedia.org/wiki/Lean_thinking
[198] Wikipedia, *Lean Six Sigma*, https://en.wikipedia.org/wiki/Lean_Six_Sigma

3.19. Smart Systems

A smart or cognitive system is a tool used by business professionals. Borrowing from the idea of the semantic web stack or the semantic web layer cake[199]; I have created the following graphic which shows the components of a smart or cognitive system:

- Trust and Collaboration Framework
- Proof, Verification, Quality Framework
- Standard Unifying Logic Framework
- Knowledge Representation and Problem-solving Framework
- Query Framework
- Area of Knowledge Theory
- Rules/Metadata/Testing
- Taxonomies and Schema
- Data Interchange and Exchange

[199] Medium, *Semantic Web Layer Cake*, https://medium.com/openlink-software-blog/semantic-web-layer-cake-tweak-explained-6ba5c6ac3fab



3.20. Measuring Quality

Increasing efficiency or productivity without maintaining quality or increasing quality is useless. It really achieves nothing.

But how exactly do you measure quality when you automate a here-to-for manual process? Without some sort of standardized set of quality metrics, comparing quality becomes an apples-to-oranges comparison.

The increased role automation plays in accounting, reporting, auditing, and analysis is inevitable. Creating quality metrics and automated verification guarantees will make sure that the automation does not come at the cost of a decrease in quality.

Measuring quality is not about developing your own quality metrics with which you evaluate yourself. Measuring quality is also for process control purposes such as Six Sigma. Measuring quality is also about the ability to perform apples-to-apples comparisons in the market place.

Without broad agreement on standard quality benchmarks, each market participant is free to highlight whatever measure of quality they feel is beneficial to them, including no measure of quality.

Quality metrics, or lack of quality metrics, incentivizes market behavior.

Quality metrics tend to work best when those measures are applied industry wide in order to make apples-to-apples comparisons. A comprehensive, standardized set of quality metrics enables a maintainable quality level throughout a process or a workflow.

Both humans and machines can be "certified" and "licensed" to perform certain specific tasks and processes. Let's face it. The average accountant is, well, average. No doubt that machines can perform certain specific tasks better than humans. Working together, leveraging the strengths of each; humans and machines can do better than either can do individually. But to make sure, quality needs to be measured.

4. Computational Professional Services

This section is inspired by the excellent paper by Michael Genesereth of Stanford University's Center for Legal Informatics, *Computational Law: The Cop in the Backseat*[200]. In that paper, the author defines *computational law* as:

"Computational Law is that branch of legal informatics concerned with the codification of regulations in precise, computable form. From a pragmatic perspective, Computational Law is important as the basis for computer systems capable of doing useful legal calculations, such as compliance checking, legal planning, regulatory analysis, and so forth."

My proposition is that these same ideas can be applied to accounting, reporting, auditing, and analysis. In fact, that paper provides an example from accounting to help the reader understand the notion of computational law.

> "Intuit's Turbotax is a simple example of a rudimentary Computational Law system. Millions use it each year to prepare their tax forms. Based on values supplied by its user, it automatically computes the user's tax obligations and fills in the appropriate tax forms. If asked, it can supply explanations for its results in the form of references to the relevant portions of the tax code."

I have briefly mentioned computational law[201], computational audit[202], computational economics[203], and computational regulation[204] (a.k.a. algorithmic regulation[205]) on

[200] Michael Genesereth, Stanford University's Center for Legal Informatics, *Computational Law: The Cop in the Backseat*, http://logic.stanford.edu/complaw/complaw.html
[201] Computational Law, http://xbrl.squarespace.com/journal/2020/8/24/computational-law.html

my blog. I would include each within the larger bucket of **computational professional services**. There are likely other business domains that might fit. But what exactly does "computational professional services" mean and how do you get it to actually work.

That is what is covered within this document. Computational professional services is exemplified by what the Data Coalition calls "smart regulation[206]" or what others call "algorithmic regulation[207]". Others use different terms. For example, Craig Lewis, Chief Economist and Director of the Division of Risk, Strategy, and Financial Innovation (RiskFin) at the SEC used the term "robo cop". We will standardize on the term computational professional services for this document.

4.1. Computational

Let me first start by explaining what I mean by computational. Per Wikipedia, a **computation**[208] is defined as:

"A computation is any type of calculation that includes both arithmetical and non-arithmetical steps and which follows a well-defined model (e.g. an algorithm)."

The key takeaway here is that by computation we don't just mean math. Computation means steps that can be followed by a computer. An algorithm.

Per Wikipedia (paraphrasing), **algorithm[209]** is defined as:

"An algorithm is a finite sequence of well-defined instructions, typically to solve a class of problems or to perform a computation. Algorithms are always unambiguous and are used as *specifications* for performing calculations, data processing, automated reasoning, and other tasks."

Computational logic[210] is the use of logic to perform or reason about computation. Logic is used to define the steps and tasks. Logic is a set of principles that forms a framework for correct reasoning. We will dive into logic a little later.

Humans are very capable of carrying out steps and performing tasks. Mechanical devices can also be created to carry out steps and perform tasks, for example a vending machine is such a device. A calculator is also such a device. Computers via the software programs they run can likewise carry out steps and perform tasks.

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[202] Computational Audit, http://xbrl.squarespace.com/journal/2020/8/25/computational-audit.html
[203] Computational Economics, http://xbrl.squarespace.com/journal/2020/8/31/computational-economics.html
[204] Computational Regulation, http://xbrl.squarespace.com/journal/2020/9/1/computational-regulation.html
[205] Tim O'Reilly, *Open Data and Algorithmic Regulation*, https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/
[206] Smart Regulation Graphic Show the Big Picture, http://xbrl.squarespace.com/journal/2012/11/12/smart-regulation-graphic-shows-the-big-picture.html
[207] Tim O'Reilly, *Open Data and Algorithmic Regulation*, https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/
[208] Wikipedia, *Computation*, https://en.wikipedia.org/wiki/Computation
[209] Wikipedia, *Algorithm*, https://en.wikipedia.org/wiki/Algorithm
[210] Wikipedia, *Computational Logic*, https://en.wikipedia.org/wiki/Computational_logic

Can computers perform all work? The answer is no. For example, computers cannot exercise professional judgment. But computers can help out with many routine, repetitious, monotonous, mechanical, boring, grueling tasks and processes of accounting, reporting, auditing, and analysis.

For additional and more information on computational and how computational systems are implemented using machines please see Turing Machine[211] and the Church-Turing Thesis[212].

4.2. Professional Services

For completeness I want to provide a definition for **professional services**. Again, Wikipedia offers a good definition[213]:

"Professional services are occupations in the service sector requiring special training in the arts or sciences. Some professional services require holding professional degrees and licenses and they also require specific skills such as architects, accountants, engineers, doctors, lawyers and teachers. Other professional services involve providing specialist business support to businesses of all sizes and in all sectors; this can include tax advice, supporting a company with accounting, IT services or providing management advice."

While what the different domains included within professional services do, there are many patterns that all domains have in common. One pattern that crosses all domains of professional services is the use of abstract symbols specific to that domain and rearranging those symbols. Let me explain.

4.3. Rearranging Abstract Symbols

Accounting, reporting, auditing, and analysis have a lot to do with professional accountants "rearranging abstract symbols". This is what I mean. In his book *Saving Capitalism*[214], Robert Reich describes three categories that all modern work/jobs fit into:

- **Routine production services** which entail repetitive tasks,
- **In-person services** where you physically have to be there because human touch was essential to the tasks,
- **Symbolic-analytic services** which include problem solving, problem identification, and strategic thinking that go into the manipulation of symbols (data, words, oral and visual representations).

In describing the third category, **symbolic-analytic services**, Mr. Reich elaborates:

"In essence this work is to **rearrange abstract symbols** using a variety of analytic and creative tools - mathematical algorithms, legal arguments, financial gimmicks, scientific principles, powerful words and phrases, visual patterns, psychological insights, and other techniques for solving conceptual puzzles. Such manipulations

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[211] Wikipedia, Turing Machine, https://en.wikipedia.org/wiki/Turing_machine
[212] Wikipedia, Church-Turing Thesis, https://en.wikipedia.org/wiki/Church%E2%80%93Turing_thesis
[213] Wikipedia, *Professional Services*, https://en.wikipedia.org/wiki/Professional_services
[214] Robert Reich, *Saving Capitalism*, page 204-206, https://www.amazon.com/Saving-Capitalism-Many-Not-Few/dp/0345806220

improve efficiency-accomplishing tasks more accurately and quickly-or they better entertain, amuse, inform, or fascinate the human mind."

Shelly Palmer breaks work tasks down in another way[215]. He points out that almost every human job requires us to perform some combination of the following four basic types of tasks:

- Manual repetitive (predictable)
- Manual nonrepetitive (not predictable)
- Cognitive repetitive (predictable)
- Cognitive nonrepetitive (not predictable)

Manual involves using one's hands or physical action to perform work. ***Cognitive*** involves using one's brain or mental action or a mental process of acquiring knowledge/understanding through thought, experience, use of the senses, or intuition.

Predictable manual or cognitive tasks can be automated. ***Unpredictable*** manual or cognitive tasks cannot be automated.

Palmer gives the example of an assembly line worker that performs mostly manual repetitive tasks which, depending on complexity and a cost/benefit analysis, can be automated. On the other hand, a CEO of a major multinational conglomerate performs mostly cognitive nonrepetitive tasks which are much harder to automate.

Many cognitive repetitive tasks in accounting, reporting, auditing, and analysis are related to symbolic-analytic services are candidates for automation.

Computational professional services is about using computers to perform cognitive repetitive tasks related to the rearrangement of abstract symbols in accounting, reporting, audit, analysis, law, or other professional services domains.

4.4. Computers

To understand how to get a computer to do work, it is important to understand the strengths of computers and the obstacles that get in the way which we will highlight now along with a few other important details.

4.5. Harnessing the Power of Computers

Important to understanding how to get computers to do what you want is understanding how computers actually work. The strengths of computers and the obstacles that get in the way of using computers were summarized well by Andrew D. Spear[216]; here is his list with some modifications made by me:

Fundamental strengths/capabilities of computers:

- **store information** reliably and efficiently (tremendous amounts)
- **retrieve information** reliably and efficiently

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[215] Shelly Palmer, *The 5 Jobs Robots Will Take Last*, https://www.linkedin.com/pulse/5-jobs-robots-take-last-shelly-palmer

[216] Andrew D. Spear in his document, *Ontology for the Twenty First Century: An Introduction with Recommendations*, page 4

- **process stored information** reliably and efficiently, mechanically repeating the same process over and over
- **instantly accessible information**, made available to individuals and more importantly other machine-based processes anywhere on the planet in real time

Major obstacles to harnessing the power of computers:

- **business professional idiosyncrasies**; different business professionals use different terminologies to refer to exactly the same thing
- **information technology idiosyncrasies**; information technology professionals use different technology options, techniques, and formats to encode and store, retrieve, and process exactly the same information
- **inconsistent domain understanding** of and technology's limitations in expressing interconnections within a domain of knowledge
- **computers are dumb beasts**; computers don't understand themselves, the programs they run, or the information that they store, retrieve, process, or provide access to

Keep in mind that the information business professionals are trying to store, retrieve, process, access, and make use of is becoming more complex than what they have been storing, retrieving, processing, and accessing in relational databases or spreadsheets for the past 50 years. For example, a financial report is complex information that is very challenging to store in a relational database and then query across millions of such reports efficiently.

4.6. Understanding what Computers Cannot Do

Key to understanding what work computers are capable of performing is understanding of what computers are not capable of doing. Computers are good at repeating tasks over and over without variation. But computers are not good at any of the following sorts of tasks:

- Intuition
- Creativity
- Innovation
- Improvising
- Exploration
- Imagination
- Judgement (such as making a tough decision from incomplete information)
- Politics
- Unstructured problem solving
- Non-routine tasks
- Identifying and acquiring new relevant information
- Compassion

Some might argue that computers can be made to mimic some of the sorts of tasks in the list above. While such arguments might be valid, performance of computers in those sorts of tasks would likely be very costly and yield results that do not meet expectations. In other words, while theoretically possible using computers for such tasks, it is generally not practical.

4.7. Knowledge Representation Approaches

The better the capability of a system to represent knowledge[217], the better the ability for a software application to read and process that knowledge and perform useful work for the user of the system.

- **A dictionary** would be a simple flat inventory of terms with no relations.
- **A thesaurus** would document some relations between broader and narrower terms. This is more useful than a simple dictionary.
- **A taxonomy** provides descriptions and a limited amount of structure generally in the form of one hierarchy. This is more useful than a thesaurus. A taxonomy is an outcome from knowledge mapping and structuring processes. A taxonomy is a hierarchical classification which helps users understand how explicit knowledge can be grouped and categorized.
- **An ontology** is a model that tends to provide descriptions and multiple structures and therefore tends to have more than one hierarchy. For example, a set of taxonomies which explicitly differentiate types of relations or associations between terms could constitute an ontology.
- **A logical theory** is a set of models (ontology-like things[218]) that are consistent with permissible per the logical theory. A logical theory provides way of thinking about a domain by means of deductive reasoning to derive logical consequences of the theory.

I have created a logical theory that describes the mechanical aspects and dynamics of a financial report[219]. But to get a knowledge-based system to work, you have to put knowledge into that system. So, what exactly constitutes a knowledge-based system?

4.8. Knowledge Based Systems (Artificial Intelligence)

The document *Expert System for Creating Financial Reports*[220] outlines the vision of a rules-based expert system for creating financial reports that leverages explainable artificial intelligence (XAI)[221]. This vision is based on working software applications,

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[217] YouTube.com, *Taxonomies, Ontologies, and Knowledge Graphs, Oh My!*, https://youtu.be/3KA__Dcb8Ns
[218] *Logic Programming and Theories*, https://digitalfinancialreporting.blogspot.com/2024/02/logic-programming-and-theories.html
[219] *Logical Theory Describing Financial Reports*, http://www.xbrlsite.com/2020/Theory/LogicalTheoryDescribingFinancialReport.pdf
[220] Charles Hoffman, CPA, *Expert System for Creating Financial Reports*, http://xbrlsite.azurewebsites.net/2022/Library/ExpertSystemForCreatingFinancialReports.pdf
[221] *Effective Automated Information Exchange and Explainable AI (XAI)*, http://xbrl.squarespace.com/journal/2022/3/21/effective-automated-information-exchange-and-explainable-ai.html

working proof of concepts, reverse engineering of XBRL-based financial reports submitted to the SEC.

There are two approaches to **artificial intelligence** and, as I have said before, the right approach should be used for the given job[222]. The two approaches are:

- **Rules-based systems** (symbolic systems, good at reasoning, expert systems, three basic types)
    - **Classification or diagnosis type**: helps users of the system select from a set of given alternatives.
    - **Construction type**: helps users of the system assemble something from given primitive components.
    - **Simulation type**: helps users of the system understand how some model reacts to certain inputs.
- **Patterns-based systems** (non-symbolic systems, good at learning, machine learning which can be supervised or unsupervised, five basic types[223])
    - **Clustering algorithms**: categorize or group things
    - **Explanatory algorithms**: explain the relationships between variables
    - **Ensemble learning algorithms**: use multiple models
    - **Similarity algorithms**: compute the similarity of pairs of things
    - **Dimensionality reduction algorithms**: reduces variables in a dataset

Another helpful breakdown of pattern-based systems is provided by the article *Top Machine Learning Algorithms for Prediction: A Short Summary*[224].

[222] *Use the Right Artificial Intelligence Approach for the Job*, http://xbrl.squarespace.com/journal/2019/7/12/use-the-right-artificial-intelligence-approach-for-the-job.html

[223] EDUCBA, Machine Learning Models, https://www.educba.com/machine-learning-models/

[224] Medium, *Top Machine Learning Algorithms for Prediction: A Short Summary*, https://medium.com/@webadmin_46735/top-machine-learning-algorithms-for-predictions-a-short-overview-5ed1ff6942ff

Name	Type	Description	Advantages	Disadvantages
Linear Regression		-The best fit line through all data points	-Easy to understand -you can clearly see what the biggest drivers odf the model are.	-sometimes to simple to capture cpmöex relationships between variables, -Tendency für the model to overfit.
Logistic Regression		-The adoption for linear regression to problembs of classification	-Easy to understand	-sometimes to simple to capture cpmöex relationships between variables, -Tendency für the model to overfit.
Decision Tree		-A graph that uses branching method to match all possible outcomes of a decision	-Easy to understand and implement.	-Not often use of ist own for prediction because it's also often too simple and not powerful enough for complex data.
Random Forest		- Takes the average of many decision trees. Each tree is weaker than the full decision tree, but combining them we get better overall performance.	-A sort of „wisdom of the crowd", Tend to result in very high quality results. -Fast to train	-Can be slow to output predictions relative to other algorithms. -Not easy to understand predictions.
Gradient Boosting		-Uses even weaker decision trees that increasingly focused on „hard examples"	-High-performing	-A small change in the future set or training set can create radical changes in the model. -Not easy to understand predictions.
Neural Networks		-Mimics the behaviour of the brain. NNs are interconnected Neurons that pass messages to each other. Deep Learning uses severak layers of NNs to put one after the other.	-Can handle extremely complex tasks. No other alsgorithm comes close in image recognition.	-very very slow to train. Because they have so many layers. Require a lot of power. -Almost impossible to understand predictions.

Currently, the expert systems working proof of concepts and commercial software that I have created and experimented with only leverage rules-based systems. But it is pretty clear that machine learning offers additional capabilities that will be inevitably leveraged.

Pacioli[225] is a logic/rules/reasoning/knowledge/insights engine. Frankly, I don't know exactly what to call Pacioli. At first, I called Pacioli a logic/rules/reasoning engine. Then I referred to it as a knowledge engine[226]. Now I am contemplating that Pacioli

[225] Auditchain, *Pacioli Logic and Rules Engine*, https://docs.auditchain.finance/auditchain-protocol/pacioli-logic-and-rules-engine

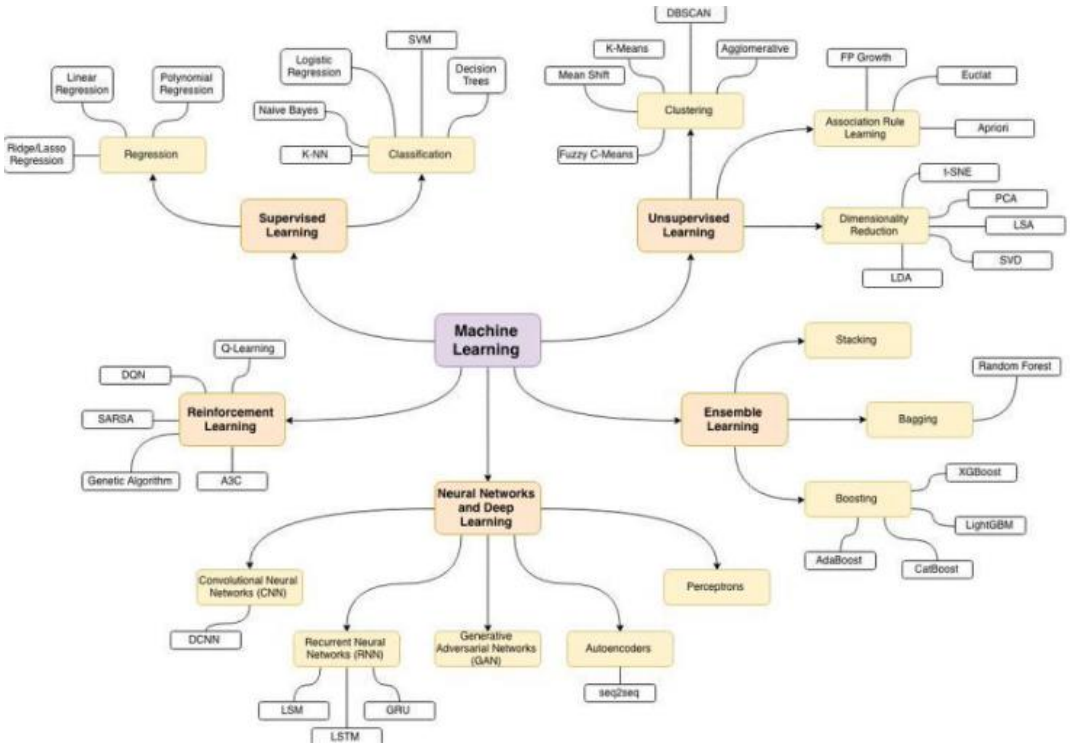
[226] *Pacioli: an XBRL Knowledge Engine*, http://xbrl.squarespace.com/journal/2022/2/19/pacioli-an-xbrl-knowledge-engine.html

is an insights engine. For now, I consider Pacioli a logic/reasoning/rules/knowledge/insights engine in order to be complete, I guess.

Pacioli has three roles. The first role of Pacioli is to enforce the financial report logical schema and return information about where a financial report might be violating that logical schema. This is helpful in the process of creating XBRL-based financial reports.

The second role of Pacioli is to leverage the machine-readable logical schema to work with the information that makes up the financial report knowledge graph[227].

The third role of Pacioli, which similarly leverages the machine-readable logical schema and financial report knowledge graph is effectively extracting information for financial analysis.



Many of these ideas are incorporated into Auditchain Luca[228] which is, as far as I can tell, the world's first expert system for creating financial reports using global standards.

4.9. Components of a Knowledge-based System

Wikipedia defines a **knowledge-based** system as follows:

"A knowledge-based system is a computer program that reasons and uses a knowledge base to solve complex problems."

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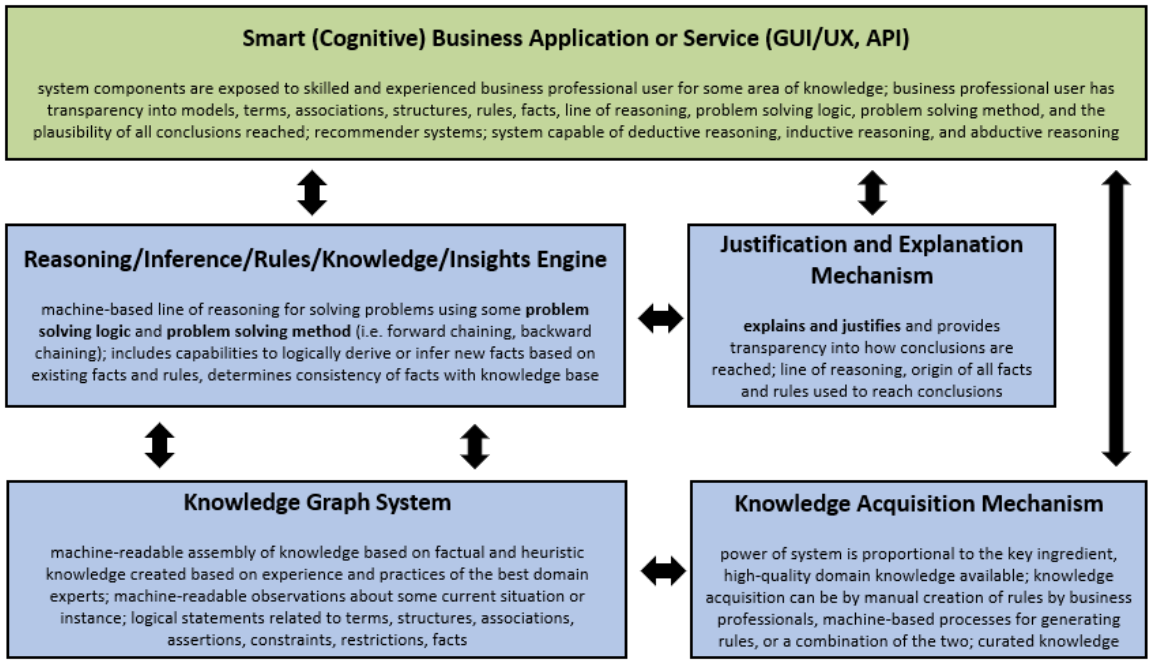
[227] Charles Hoffman, CPA, *Financial Report Knowledge Graphs*, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf

[228] *Getting Started with Auditchain Luca*, https://digitalfinancialreporting.blogspot.com/2024/01/getting-started-with-auditchain-luca.html

Information is acquired from skilled, knowledgeable professionals. This information is stored in a knowledge base and a fact database. The system applies problem solving logic using a problem-solving method. The knowledge-based system supplies an explanation and justification mechanism to help users understand the line of reasoning used to reach conclusions. The system then presents that information back to the user.

Nothing is a "black box". The origin of information used to reach conclusions is always apparent to the users of the application.

The following graphic provides a summary of the components of a knowledge-based system:



The following describes each of those components:

- **Knowledge acquisition mechanism**: Somehow knowledge needs to be acquired and put into the knowledge-based system.
- **Knowledge graph system**
  - **Knowledge base**: Somehow the knowledge acquired needs to be stored in machine-readable form such that it can be used by the system.
  - **Fact database**: Similarly, facts need to be stored in machine-readable form such that they can be used by the system.
- **Reasoning, inference, rules engine**: Some rules engine is necessary to process the knowledge and facts. Deductive reasoning is essential; inductive reasoning is a nice-to-have.
- **Justification and explanation mechanism**: Nothing in the system should be a black box. Users of the system must be able to understand the origin of information (providence) and there needs to be an audit trail to understand every decision made and the reasoning behind the system.

- **Business professional user interface**: Business professionals need to interact with the system to be able to perform work on their terms. Technical complexity must be buried deep within the application, business professionals don't care about technical details. Domain complexity is what users should be working with.

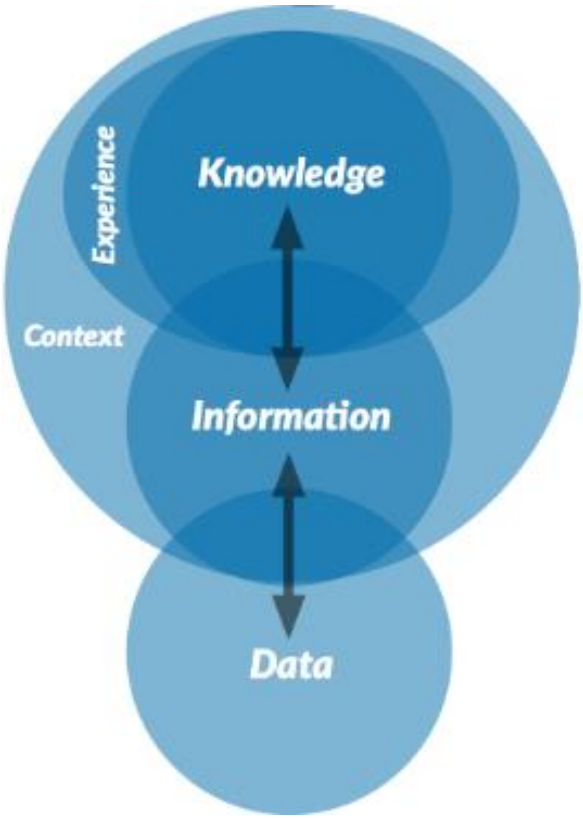
4.10. From Data to Information to Knowledge

Information is meaningful, data is not. Within professional services we are working with information, not data.

The difference between *data* and *information* is that data is the raw numbers and words where information is data in context. This is important to understand as most problems faced by accountants are an information problem, rather than a data problem. Getting data is easy. Knowing what that data represents and how the data fits together is difficult. Representing information in the form that a machine such as a computer can understand and use that information is difficult.

Knowledge is a set of data and information and a combination of skill, know-how, experience which can be used to improve the capacity to take action or support a decision making process.

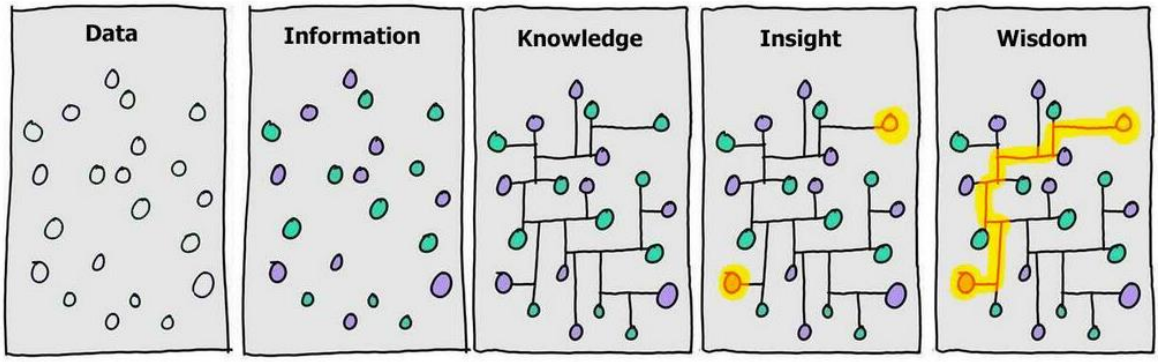
The following graph created by Shawn Riley shows the important to understand differences between data, information, and knowledge[229].



[229] Shawn Riley, *Machine Learning versus Machine Understanding*, https://www.linkedin.com/pulse/machine-learning-vs-understanding-shawn-riley/

The important point to understand here is that it takes the skill and experience of human professionals to create information and knowledge.

Here is another graph that helps one understand the difference between data, information, knowledge, insight, and wisdom[230]:



4.11. Difference Between Machine-readable, Machine-understandable, Machine-interpretable

In my popular video, *How XBRL Works*[231], I try and explain the difference between information structured for presentation and information structured for meaning. That video is worth watching. But I want to expand that explanation to include the notions of "machine-readability", "machine-understandable", and "machine-interpretable". This spectrum will help you dial in your understanding of the capabilities of computers. If you want all of the details for the examples provided below, please see the SFAC 6 Elements of Financial Statements[232] representation.

4.12. Machine-readable

Fundamentally, anything that a computer interacts with has to be structured in some way. Word processing documents, PDF documents, and HTML documents are structured and machine readable; but all of those document formats are structured for the presentation of information in the form of pages, paragraphs, tables, sentences, and other such structures that contain information and a computer. But a computer does not understand the information that is being conveyed by such documents.

Likewise, even an XBRL-based report is machine-readable but the information contained within the report is not understandable to the computer. Here is a screenshot of a small XBRL-based report[233]:

[230] Tumblr, Information vs Knowledge, https://informationversusknowledge-blog.tumblr.com/
[231] YouTube.com, How XBRL Works, https://www.youtube.com/watch?v=nATJBPOiTxM
[232] SFAC 6 Representation, http://xbrlsite.azurewebsites.net/2020/master/sfac6/
[233] SFAC 6 Representation, Machine Readable, http://xbrlsite.azurewebsites.net/2020/master/sfac6/instance.xml

```
<sfac6:Assets contextRef="I-2019" unitRef="U-U-USD" decimals="INF">0</sfac6:Assets>
<sfac6:Assets contextRef="I-2020" unitRef="U-U-USD" decimals="INF">3500</sfac6:Assets>
<sfac6:Liabilities contextRef="I-2019" unitRef="U-U-USD" decimals="INF">0</sfac6:Liabilities>
<sfac6:Liabilities contextRef="I-2020" unitRef="U-U-USD" decimals="INF">0</sfac6:Liabilities>
<sfac6:Equity contextRef="I-2019" unitRef="U-U-USD" decimals="INF">0</sfac6:Equity>
<sfac6:Equity contextRef="I-2020" unitRef="U-U-USD" decimals="INF">3500</sfac6:Equity>
<sfac6:Revenues contextRef="D-2020" unitRef="U-U-USD" decimals="INF">7000</sfac6:Revenues>
<sfac6:Revenues contextRef="D-2020" unitRef="U-U-USD" decimals="INF">7000</sfac6:Revenues>
```

A computer program such as an XBRL processor can read that information shown above. But a computer is unaware of what information is being represented. A computer does not innately understand the information. Remember, computers are dumb beasts that need to be led by the hand in order to get them to understand.

4.13. Machine-understandable

While a computer may not understand the meaning of the information, there are some things that the computer does understand. A machine can take the same information shown above and turn it into this[234]:

Comprehensive Income Statement [Line Items]	Period [Axis] 2020-01-01 - 2020-12-31
Comprehensive Income [Roll Up]	
Revenues	7,000
(Expenses)	(3,000)
Gains	1,000
(Losses)	(2,000)
Comprehensive Income	3,000

If a machine is given additional information about how to render the information, then the machine can understand how to render the information that it is provided; but it still does not actually understand the information that it is working with.

Now, you can provide that understanding; that is not a problem. We will explain this more in a moment. But what we want you to recognize is that is exactly what you need to do; provide the understanding to the computer.

4.14. Machine-Interpretable

Once a machine does understand; to the extent of that understanding a machine can interpret information and then take action based on that interpretation.

So, for example, if you provide the understanding that "If the value of comprehensive income is less than $5,000; then SELL the company to remove the company from your investment portfolio," because you have knowledge (i.e. you

[234] SFAC 6 Representation, Human Readable, http://xbrlsite.azurewebsites.net/2020/master/sfac6/evidence-package/contents/Rendering-N1-RE8.html

believe) that companies with comprehensive income of less than $5,000 are not good investments.

4.15. Rules

The Merriam-Webster dictionary defines anarchy[235] as "a situation of confusion and wild behavior in which the people in a country, group, organization, community, etc., are not controlled by rules or laws." Rules prevent information anarchy[236].

Rules enable a knowledge bearer to describe information they are providing and verify that the information provided is consistent with that description. Rules enable a knowledge receiver to understand the description of information provided by the knowledge bearer and likewise verify that the information is consistent with that description.

Rules guide, control, suggest, or influence behavior. Rules cause things to happen, prevent things from happening, or suggest that it might be a good idea if something did or did not happen. Rules help shape judgment, help make decisions, help evaluate, help shape behavior, and help reach conclusions.

Rules arise from the best practices of knowledgeable business professionals. A rule is a rule that describes, defines, guides, controls, suggests, influences or otherwise constrains some aspect of knowledge or structure within some problem domain.

Don't make the mistake of thinking that business rules are completely inflexible and that you cannot break rules. Sure, maybe there are some rules that can never be broken. Maybe there are some rules that you can break. It helps to think of breaking rules as penalties in a football game. The point is that the guidance, control, suggestions, and influence offered by rules are a choice of business professionals. The meaning of a rule is separate from the level of enforcement someone might apply to the rule.

4.16. "Rules as Code" (i.e. Machine-readable Rules)

In his Ted Talk, Jason Morris discusses the notion of "rules as code"[237]. Rules as code is a methodology for creating and applying legal rules, accounting rules, reporting rules, auditing rules and such in the digital age. Some of the important features of Rules as Code are[238]:

- Legislation, statutes, and regulations should be drafted in a natural language and in the form of machine-readable rules at the same time.
- Rules should be declarative.
- The platform on which the legislation is encoded should be open, accountable, transparent and standardized.

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[235] Anarchy definition, Merriam-Webster, http://www.merriam-webster.com/dictionary/anarchy
[236] *Understanding that Business Rules Prevent Anarchy*, http://xbrl.squarespace.com/journal/2016/7/15/understanding-that-business-rules-prevent-anarchy.html
[237] YouTube.com, Jason Morris, *How programming can make the law more accessible*, https://youtu.be/d5Mt-Q9K7tU
[238] American Bar Association, Jason Morris, *Rules as Code*, https://www.lawpracticetoday.org/article/rules-code/

- Definitions should be consistent across all acts, statutes, and regulations; not only within them. Each law should add to the shared dictionary of terms.

4.17. Network Affect

The network effects[239] (Metcalf's Law[240]) have become an essential component of a successful digital businesses. Network effects typically account for 70% of the value of digitally-related companies. Metcalfe's Law states that a network's impact is the square of the number of nodes in the network.

The Internet itself has become a facilitator for network effects. As it becomes less and less expensive to connect users on platforms, those able to attract them in mass become extremely valuable over time. Also, network effects facilitate scale. As digital businesses and platforms scale, they gain a competitive advantage, as they control more of a market.

For more information about the network affect, I would recommend *New Rules for the New Economy*[241]. The thesis of *New Rules for the New Economy* is that we are now living in an economy based on ideas and communication rather than energy and atoms. Further, this "new" economy has distinct laws or rules so it behaves differently than the previous industrial economy. To do well in the new regime, we need to grasp the new dynamics of information.

4.18. Gamified Incentive Model

Per Wikipedia, gamification[242] is the strategic attempt to enhance systems, services, organizations and activities in order to create similar experiences to those experienced when playing games in order to motivate and engage users of a system.

Gamification was introduced by John von Neumann and Oskar Morgenstern's *Theory of Games and Economic Theory*[243]. Now it is commonly referred to game theory or gamification.

A game[244] is defined as any interaction between multiple parties in which each party's payoff is affected by the decisions of others.

Gamified incentive model is a way of thinking about how parties interact with one another.

4.19. Logic

Logic is a set of principles that forms a **framework for correct reasoning**. Logic is a process of deducing information correctly. Logic is about the correct methods that

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[239] Wikipedia, *Network Effect*, https://en.wikipedia.org/wiki/Network_effect
[240] Metcalf's Law, https://www.thegeniusworks.com/2020/02/metcalfes-law-explains-how-the-value-of-networks-grow-exponentially-there-are-5-types-of-network-effects/
[241] Kevin Kelly, *New Rules for the New Economy*, http://xbrl.squarespace.com/journal/2021/4/5/new-rules-for-the-new-economy.html
[242] Wikipedia, Gamification, https://en.wikipedia.org/wiki/Gamification
[243] Neumann and Oskar Morgenstern, *Theory of Games and Economic Theory*, https://books.google.com/books?id=jCN5aNJ-n-0C&printsec=frontcover#v=onepage&q&f=false
[244] YouTube.com, *Game Theory: The Science of Decision-Making*, https://youtu.be/MHS-htjGgSY

can be used to prove a statement is true or false. Logic tells us exactly what is meant. Logic allows systems to be proven.

The principles of logic are topic-neutral, universal principles which are more general than say the single domain of law, biology, mathematics, accounting, or economics. Logic has to do with the meaning of concepts common to all domains and establishes general rules governing concepts.

Logical truths are necessary. The principles of logic are derived solely using reasoning and the validity of the universal principles are not dependent on any other feature of the world.

Logic is the process of deducing information correctly; **logic is not about deducing correct information**. Understanding the distinction between *correct logic* and *correct information* is important because it is important to follow the consequences of an incorrect assumption. Ideally, we want both our logic to be correct and the facts we are applying the logic to, to be correct.

The point here is that correct logic and correct information are two different things. If our logic is correct, then anything we deduce from such information will also be correct per the rules of logic.

As we pointed out, logic plays an important role in achieving computational professional services. But which logic?

4.20. Metalogic

Enter the notion of metalogic[245]. **Metalogic** relates to the comparison between the logic of different systems. As pointed on in *Specifying the Rule Metalogic on the Web*[246], interoperability issues can become problematic if you are using different logics to perform work and evaluate two different logical systems such as two different financial report models. Both systems, although different software applications, should derive the same logical conclusions.

Now, I have mentioned that there are a number of different logic systems that could be used to represent a logical system: OWL+SHACL+RDF, Modern Prolog, ISO Prolog, Datalog, PSOA, GQL/Cypher, XBRL+More, SQL+More[247] . We will discuss these different implementation alternatives in a moment.

And so, can you prove the same things in one of the systems mentioned above in another one of the systems above? Or saying this another way, is the logic of say OWL+SHACL+RDF equivalent to that of say Modern Prolog? Logical interoperability is important. In fact, interoperability in general is important.

[245] Ted Sider, Logic of Philosophy, page 6, http://tedsider.org/books/lfp_sample.pdf#page=6
[246] Harold Boley, *Specifying the Rule Metalogic on the Web*, http://ruleml.org/ruleml.org/metalogic/RuleMetaLogic2011-10-29.pdf
[247] Answering the Question of Which Logic, http://xbrl.squarespace.com/journal/2020/8/15/answering-the-question-of-which-logic.html

4.21. Interoperability

There have been many different ways to explain what interoperability is and how to achieve it; it seems that there is convergence emerging on this four-level interoperability model[248,249]:

- **Foundational** (Level 1): Establishes the *inter-connectivity requirements* needed for one system or application to securely communicate data to and receive data from another.
- **Structural** (Level 2): Defines the *format, syntax and organization of data exchange* including at the data field level for interpretation.
- **Semantic** (Level 3): Provides for *common underlying models and codification of the data* including the use of data elements with standardized definitions from publicly available value sets and coding vocabularies, providing shared understanding and meaning to the user.
- **Organizational** (Level 4): Includes *governance, policy, social, legal and organizational considerations* to facilitate the secure, seamless and timely communication and use of data both *within and between* organizations, entities and individuals. These components enable shared consent, trust and integrated end-user processes and workflows.

Standards help provide interoperability. For example,

- XBRL International[250] provides the XBRL technical syntax[251] global standard (including a conformance suite for testing software) to enable syntax interoperability
- Object Management Group[252] (OMG) provides the Standard Business Report Model[253] (SBRM) to provide a logical conceptualization of a business report
- RuleML[254] helps to provide business rule and logic interoperability
- Logical Theory Describing Financial Report[255] provides semantics of a financial report, building on the SBRM model of a business report

All this complexity makes it appear that computational professional services will be impossible for a business professional to make use of. Can't we just get rid of some of these details, reducing the complexity? Well, let us talk about complexity.

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[248] HIMSS, Interoperability in Healthcare, https://www.himss.org/resources/interoperability-healthcare
[249] Shawn Riley, *What is Interoperability*, https://www.linkedin.com/posts/shawnriley71_what-is-interoperability-it-is-the-ability-activity-6703288197729918976-FFYD/
[250] XBRL International, XBRL, http://xbrl.org
[251] XBRL International, Standards, https://specifications.xbrl.org/specifications.html
[252] OMG, https://www.omg.org
[253] OMG, Standard Business Report Model (SBRM), https://www.omg.org/intro/SBRM.pdf
[254] RuleML, http://wiki.ruleml.org/index.php/RuleML_Home
[255] Logical Theory Describing Financial Report, http://xbrl.squarespace.com/logical-theory-financial-rep/

4.22. Complexity

The ***Law of Conservation of Complexity*** states: "Every application has an inherent amount of irreducible complexity. The only question is: Who will have to deal with it-the user, the application developer, or the platform developer?" Another version of the law of conservation of complexity: "Every application has an inherent amount of complexity that cannot be removed or hidden. Instead, it must be dealt with, either in product development or in user interaction."

Irreducible Complexity is explained as follows: A single system which is composed of several interacting parts that contribute to the basic function, and where the removal of any one of the parts causes the system to effectively cease functioning.

So, for example, consider a simple mechanism such as a mousetrap. That mousetrap is composed of several different parts each of which is essential to the proper functioning of the mousetrap: a flat wooden base, a spring, a horizontal bar, a catch bar, the catch, and staples that hold the parts to the wooden base. If you have all the parts and the parts are assembled together properly, the mousetrap works as it was designed to work.

But say you remove one of the parts of the mousetrap. The mousetrap will no longer function as it was designed; it will not work. That is **irreducible complexity**: the complexity of the design requires that it can't be reduced any farther without losing functionality.

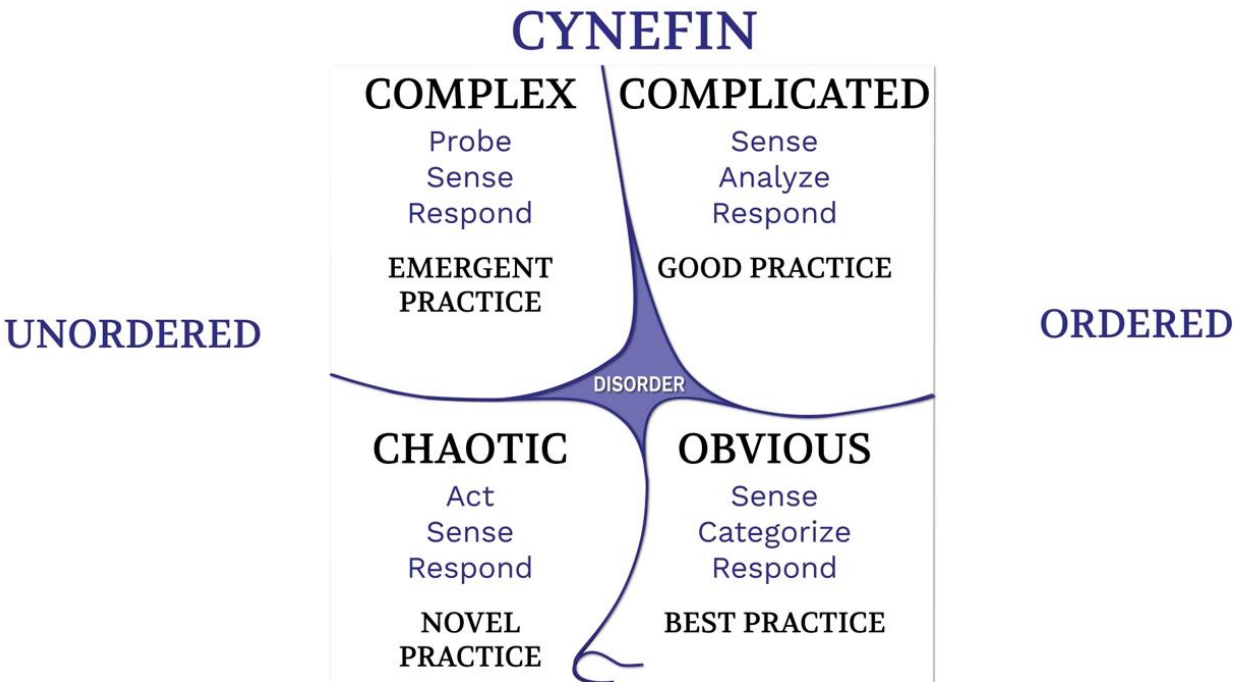
Anyone can create something that is complex. It is much harder to create something that is sophisticated and simple. Simple is not the same thing as simplistic. "Simple" is not about doing simple things. Simplicity is "dumbing down" a problem to make the problem easier to solve. Simple is about beating down complexity in order to make something simple and elegant; to make sophisticated things simple to use rather than complex to use.

Creating something that is simple takes conscious effort and is hard work. But that is what is necessary to make computational professional services work as desired.

The Cynefin Framework[256] is a conceptual framework for decision making and thinking about complexity. The framework was created in 1999 by David Snowden of IBM Global Services to help IBM to manage intellectual capital.

For more information about the Cynefin framework, I would recommend the video *Complexity, Cynefin, and Agile*[257]. The Cynefin framework helps you understand the difference between ordered systems and unordered systems; best practices, good practices, and novel practices; simple, complicated, and complex systems; and other such dynamics.

[256] Wikipedia, *Cynefin Framework*, https://en.wikipedia.org/wiki/Cynefin_framework
[257] YouTube.com, Complexity, Cynefin, and Agile, https://youtu.be/-F4enP8oBFM



4.23. Computation, Mathematics, Logic and Language

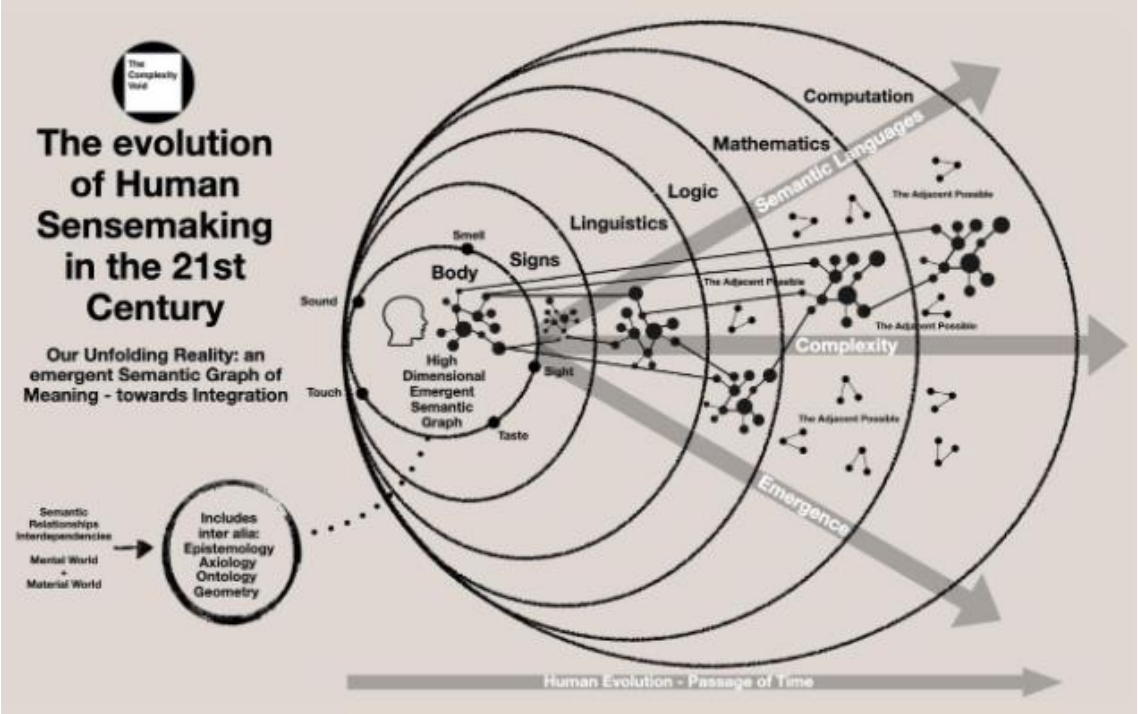
Sensemaking[258] is the process of determining the deeper meaning or significance or essence of the collective experience for those within an area of knowledge. The article, *The Semantic Abstraction of our Material World…*[259] provides a graphic of the evolution of sensemaking.

Sensemaking is a tool. You can use sensemaking to construct a map you can share with others. Sensemaking is the art of analyzing, understanding, clarifying, untangling, organizing, and synthesizing. Sensemaking involves:

- Looking for patterns in information.
- Making connections among different things.
- Synthesizing lots of information and categorizing it into small chunks.
- Think about the big picture.
- Think about the "why" of a situation.
- Organizing and untangling things.

Professionals need to become sensemakers and learn to communicate effectively with software engineers.

[258] Sensemaking, http://xbrl.squarespace.com/journal/2021/11/18/sensemaking.html
[259] Richard Schutte, The Semantic Abstraction of our Material World…, https://richardschutte.medium.com/the-semantic-abstraction-of-our-material-world-53da868ce53e



4.24. Universal vs Domain Specific Applications

Having high-level metamodels such as the forthcoming Standard Business Report Model[260] (SBRM) and Logical Theory Describing Financial Report[261] (see). Plus, creating the base metadata, such as the US GAAP Financial Reporting Metadata[262] leveraging that high-level metamodel makes all of this extremely technical stuff far less technical to business professionals. How? A few trained professionals create the high-level metadata but every software application and business domain professional benefits from that metadata and high-level models. Further, software creation costs are reduced. How is that possible? Read on.

In his book *Systematic Introduction to Expert Systems*[263], Frank Puppe provides the graphic below. The graphic basically points out that **universal, general tools** are less restrictive but cost more to create than **domain-specific tools**. In addition to universal, general tools being more costly to create and more difficult to create; domain specific tools are easier to create and much, much easier for business professionals to use because of the restrictions.

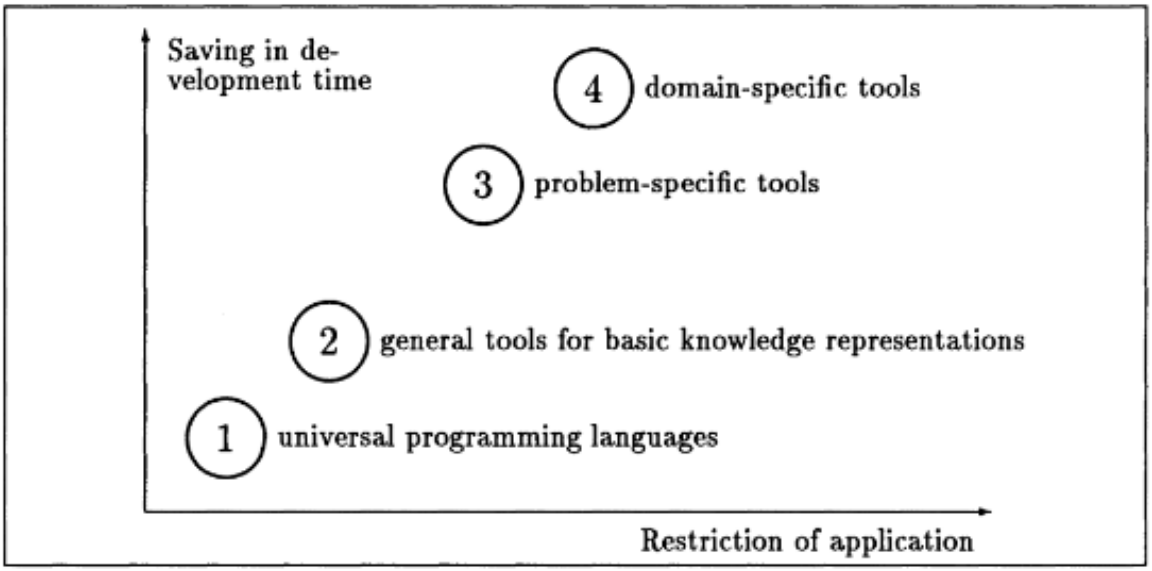
So, a "restriction" is not a flaw. **The restriction is what makes the tool easier to use and cost less and make easier to develop**. You don't need the universe of

[260] *SBRM Progress Report*, http://xbrl.squarespace.com/journal/2020/1/30/sbrm-progress-report.html
[261] *Logical Theory Describing Financial Report*, http://xbrl.squarespace.com/logical-theory-financial-rep/
[262] *US GAAP Financial Reporting Scheme*, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Home.html
[263] Frank Puppe, *Systematic Introduction to Expert Systems*, page 11, https://books.google.com/books?id=_kKqCAAAQBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

all possible options for a specific domain; you only need to create what that specific domain needs. As **long as you get these restrictions correct**, they really are not "restrictions" of the domain, they are the "boundaries" of the domain. You don't need them.

Technical people don't typically understand these business domain boundaries. Many times, to play it safe technical people add flexibility in order to make certain that business domain user needs are being met. But this flexibility comes at a cost. Additional costs are incurred to create the flexibility and software is harder to use because business professionals need to figure out which option they should use.

Business domain people do understand the boundaries if they think about them. Many business professionals cannot properly articulate the appropriate boundaries or restrictions. This communications problem tends to lead to software that costs more to create than is necessary and harder to use than necessary.



This is not an either-or choice. Sometimes universal tools are very appropriate. Other times domain-specific tools are appropriate. Being conscious of these dynamics will lead to the right software being created and the appropriate level of usability. Universal tools are not a panacea. Unconsciously constricting a domain-specific tool when it would have been better to create a more universally usable tool also can be a mistake one makes.

Today, everyone is competing at the "universal tool" level and not one of those universal tools is usable by business professionals. Computational Professional Services is a vertical; but it is an incredibly WIDE (i.e. horizontal) vertical market.

4.25. Process Control

Because, as we pointed out, financial reports are not static form and therefore individual economic entities are allowed to make specific modifications to models; those modifications need to be controlled in order to maintain information quality. Said another way, permissible modifications to the model must be crystal clear to those making such modifications.

4.26. Control + Rules = Effective Automation (High Quality)

If a process cannot be controlled then the process simply cannot repeatedly and reliably output high-quality. If process output is not high-quality, automation cannot possibly be effective.

So, control of a process is necessary in order for the process to be effective. How do you control a process? You control a process using rules. Manual processes are controlled by rules that are read by humans. Automated processes are controlled by rules that are readable by both machines (i.e., to execute the process) and humans (i.e., to make sure the rules are right).

Who creates these machine-readable rules that are used to control processes that yield effective automation? Accountants must create these rules because the rules tend to be accounting oriented. Technical rules tend to relate to syntax and such technical rules can be hidden from business professionals. What is left is the business logic and accounting rules that are used to control information and control process workflow. As such, the creation of machine-readable rules must be "self-service". Business professionals must be empowered to create, adjust, maintain, and otherwise manage the rules that are used to control and therefor effectively automate processes. Once you have the machine-readable rules, you need software that can process the rules; this is sometimes called a rules engine or reasoning engine or a semantic reasoner. We will get to that in a bit, but first let's be sure you have some critically important background understanding.

4.27. Lean Six Sigma

Lean Six Sigma[264] is a discipline that combines the problem-solving methodologies and quality enhancement techniques of Six Sigma[265] with the process improvement tools and efficiency concepts of Lean Manufacturing[266]. Born in the manufacturing sector, Lean Six Sigma works to produce products and services in a way that meets consumer demand without creating wasted time, money and resources.

Specifically, Lean is 'the purposeful elimination of wasteful activities.' It focuses on making process throughout your company faster, which effects production over a period of time. Six Sigma works to develop a measurable process that is nearly flawless in terms of defects, while improving quality and removing as much variation as possible from the system.

Quality and the lack of quality both have a cost. The 1-10-100 Rule is related to what's called "the cost of quality." Essentially, the rule states that prevention is less costly than correction is less costly than failure. It makes more sense to invest $1 in prevention, than to spend $10 on correction. That in turn makes more sense than to incur the cost of a $100 failure[267].

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[264] Wikipedia, *Lean Six Sigma*, https://en.wikipedia.org/wiki/Lean_Six_Sigma

[265] Wikipedia, *Six Sigma*, https://en.wikipedia.org/wiki/Six_Sigma

[266] Wikipedia, *Lean Manufacturing*, https://en.wikipedia.org/wiki/Lean_manufacturing

[267] Michael Canic, *The Cost of Quality: The 1-10-100 Rule*, https://www.makingstrategyhappen.com/the-cost-of-quality-the-1-10-100-rule/

To learn more about Lean Six Sigma techniques, principles, tools, and philosophies I would recommend the chapter *Lean Six Sigma*[268] of *Mastering XBRL-based Digital Financial Reporting*.

4.28. Building on the Shoulders of Giants

Rather than "reinventing the wheel" sometimes it is better to build on the shoulders of giants (i.e. existing, proven standard technologies).

A logical system[269] is a type of formal system[270]. A financial report is a type of formal system. To be crystal clear what I am trying to create is a **finite model-based deductive first-order logic system**[271].

"Finite" as opposed to "infinite" because finite systems can be explained by math and logic, infinite systems cannot. "Model-based" is the means to address the necessary variability (i.e. required flexibility) inherent in the required system. "Deductive", or rule-based, as contrast to inductive which is probability based which is not appropriate for this task. "First-order logic" because first-order logic can be safely implemented within software applications and higher order logics are unsafe. "System" because this is a system.

The point is to create a logical system that has high expressive capabilities but is also a provably safe and reliable system that is free from catastrophic failures and logical paradoxes which cause the system to completely fail to function. To avoid failure, computer science and knowledge engineering best practices seems to have concluded that the following alternatives are preferable:

- **Systems theory**: A system[272] is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Systems theory explains logical systems.
- **Logical theory**: (a.k.a. logical system) There are many approaches to representing "ontology-like things" in machine-readable form[273], a logical theory being the most powerful.
- **Proof theory**: The ideas of proof theory[274] can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems.
- **Set theory**: Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory[275] is preferred to naïve set theory.

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[268] Charles Hoffman, CPA, asdf, http://www.xbrlsite.com/mastering/Part01_Chapter02.K_LeanSixSigma.pdf
[269] Wikipedia, *Logical Systems*, https://en.wikipedia.org/wiki/Logic#Logical_systems
[270] Wikipedia, *Formal System*, https://en.wikipedia.org/wiki/Formal_system
[271] Wikipedia, *First-order Logic, Deductive System*, https://en.wikipedia.org/wiki/First-order_logic#Deductive_systems
[272] Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory
[273] Difference between Taxonomy, Conceptual Model, Logical Theory, http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html
[274] Stanford University, *The Development of Proof Theory, The Aims of Proof Theory*, https://plato.stanford.edu/entries/proof-theory-development/#AimProThe

- **Graph theory**: Directed acyclic graphs[276] are preferred to less powerful "trees" and graphs which contain cycles that can lead to catastrophic problems caused by those cycles.
- **Logic**: Logic is a formal communications tool. **Horn logic**[277] is a subset of first-order logic which is immune from logical paradoxes should be used as contrast to more powerful but also more problematic first order logic features. Note that deductive reasoning is leveraged for the process of creating a financial report and not inductive reasoning (i.e. machine learning)
- **Model theory**: Model theory is a way to think about flexibility. Safer finite model theory[278] is preferable to general model theory.
- **World view**: The following are common issues which appear when implementing logical systems in machine-readable form, the safest and most reliable alternatives are:
    - closed world assumption[279] which is used by relational databases is preferred to the open world assumption which can have decidability issues[280];
    - negation as failure[281] should be explicitly stated;
    - unique name assumption[282] should be explicitly stated;

Business professionals are (a) not capable of having precise discussions of these sorts of issues with software engineers, (b) don't care to have such technical discussions about these sorts of issues with software engineers, (c) are not interested in the theoretical or philosophical or religious debates that commonly exist related to these alternatives, (d) if the alternatives were appropriately articulated to a business professional, who tend to be very practical, they would **most often error on the side of safety and reliability**.

While some implementations can have decidability issues or termination problems or other such issues, a master craftsman is knowledgeable of these issues and so they can work around such problems.

4.29. Effective Computational Professional Services

Clearly for computational professional services to be useful, it actually needs to work, be reliable, be predictable, and provide benefits in terms of better, faster, or cheaper professional services offerings.

'Hope' is not a sound engineering principle. To make computational professional services work one needs "know how". Know how is a type of practical knowledge. A

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[275] Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory
[276] Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph
[277] Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause
[278] Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory
[279] Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption
[280] Wikipedia, *Undecidability Problem*, https://en.wikipedia.org/wiki/Undecidable_problem
[281] Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure
[282] Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption

best practice is a method or technique that has been generally accepted as superior to any other known alternatives because it produces results that are superior to those achieved by other means or because it has become a standard way of doing things.

Rather than rushing into the details; take a step back consider the utility that a framework, theory, principles, and method would very likely provide. Then, brick-by-brick, much like building a house, business domain experts and software engineers can create tools that automate certain types of tasks in that process and let computational professional services unfold.

Computational professional services is not about computers replacing humans. Computational professional services is about using machines to do what they do best and humans to do what they do best. Computational professional services is about human-machine collaboration; much like how a calculator is used to help humans do math. Computational professional services is about augmenting the capabilities of humans by leveraging machines.

4.30. Framework, Theory, Principles, Method

What is conspicuously lacking from most people's minds is a broad framework let alone a theory and principles on how to think about computational professional services.

A **framework** is an aid that enables a community of stakeholders with a set of rules, ideas, or beliefs which provides a structure in order to think about or implement something. A **theory** enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important statements used for capturing meaning or representing a shared understanding of and knowledge in some universe of discourse. **Principles** help you think about something thoroughly and consistently. Overcoming disagreements between stakeholders and even within groups of stakeholders is important and principles can help in that communications process. A good practices/best practices based method[283] for creating a process control mechanism that consistently yields high-quality XBRL-based financial reports where the model can be "reshaped" or "altered" by report creators has been created and tested and consistently yields high-quality XBRL-based financial reports.

The *Logical Theory Describing Financial Report*[284]provides a framework, theory, and principles for thinking about XBRL-based digital financial reporting. This can serve as an example of how to think about computational professional services.

4.31. Merkle DAG, Merkle Tree, Merkle Proof

Knowledge graphs[285], DAGs (a.k.a. directed acyclic graphs[286]), Merkle Trees[287], and Merkle Proofs[288] will transform (are transforming) accounting, reporting, auditing, and analysis profoundly and forever.

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[283] Charles Hoffman, CPA, *Method – Terse Explanation*, http://xbrlsite.azurewebsites.net/2020/library/MethodTerse.pdf
[284] Charles Hoffman, CPA, Logical Theory Describing Financial Report, http://xbrl.squarespace.com/logical-theory-financial-rep/
[285] Knowledge Graphs, http://xbrl.squarespace.com/journal/2021/6/27/the-knowledge-graph-cookbook-recipes-that-work.html

As I have pointed out previously[289], an XBRL-based financial report is a knowledge graph. Not only are such reports knowledge graphs, they are special types of knowledge graphs that don't have "loops" or cycles. Those special types of knowledge graphs are called directed acyclic graphs.

A Merkle DAG[290] is a type of Merkle Tree. You can create a Merkle DAG from the information contained within an XBRL-based digital financial report. When thinking about this, most software engineers think about a hash of the XBRL technical syntax that makes up the report. But you can also think of this while considering the logic of the digital financial report. That logic is represented by all of the rules related to the report that has been represented using the XBRL technical syntax.

A Merkle proof[291] is an approach to verifying that information stored, transferred, handled, processed, or otherwise used by a computer has not been changed or otherwise tampered with. You can also verify that the rules used to verify the logic of the report have not been changed.

The IterPlanetary File System (IPFS)[292] is a peer-to-peer distributed file system that seeks to connect all computing devices with the same system of files. Today, the internet uses location-based addressing. IPFS uses content-based addressing. So, for example, an auditor can verify that an XBRL-based financial report is considered complete, consistent, and properly functioning and the set of rules used to make that determination can be both defined and specified; included in the Merkle DAG and proven using the Merkle proof. This provides unprecedented transparency and potentially trust.

My method[293] specifies a minimum set of information that must be used to verify an XBRL-based financial report. Effectively, that method defines a level 5 financial report[294].

If you use Merkle trees and Merkle proofs to verify *the report* and put those hashes on a publicly available digital distributed ledger then you can make known specifically what was reported, understand what information was used to verify that reported information, and be sure that the information has not been tampered with. This, I guess, is how you would create a level 6 digital financial report.

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[286] YouTube.com, *Quick Tip - What's a DAG, and Why Should I Care?*, https://youtu.be/IltIGJOHYgo
[287] Changlly, *Merkle Trees Explained*, https://changelly.com/blog/merkle-tree-explain/
[288] Medium, Merkle Proof Explained, https://medium.com/crypto-0-nite/merkle-proofs-explained-6dd429623dc5
[289] Understanding Financial Reports are Knowledge Graphs, http://xbrl.squarespace.com/journal/2021/6/18/understanding-financial-report-knowledge-graph.html
[290] IPFS, *Merkle DAG*, https://docs.ipfs.io/concepts/merkle-dag/
[291] Medium, *Merkle Proof Explained*, https://medium.com/crypto-0-nite/merkle-proofs-explained-6dd429623dc5
[292] IPFS, http://xbrl.squarespace.com/journal/2021/8/15/ipfs.html
[293] Method – Terse Explanation, http://xbrlsite.azurewebsites.net/2020/library/MethodTerse.pdf
[294] Financial Report Levels, http://xbrl.squarespace.com/journal/2021/4/5/financial-report-levels.html

If you use a Merkle tree and Merkle proof at the transaction level you could not only verify the report but also verify the set of transactions which were used to generate that report. This, I guess, is how you would create a level 7 digital financial report.

Wow! This is all based on mathematics. Here's is a prototype XBRL-based financial report[295] plus 94% of the rules that I have come up with to make that report consistent with my method. Here is another prototype that includes the transactions[296] and, I believe, has 100% of the core rules necessary.

4.32. Immutable Digital Distributed Ledgers

A digital distributed ledger is an indestructible and un-editable decentralized computer record, or ledger. A digital distributed ledger provides a full and complete history of transactions in that ledger. Ledgers can be as public and open or private and limited as the use case demands. Ledgers can be permissioned or permission less in determining who can add new transactions. Different approaches can be used to determine how new transactions are authorized (proof-of-stake, proof-of-work, consensus, identity mechanisms) before they can add new information to the ledger. Ledgers can be interlinked with one or more other ledgers.

To find out more about digital distributed ledgers please read the chapter *Digital Distributed Ledgers*[297] in Mastering XBRL-based Digital Financial Reporting[298].

5. Knowledge Graphs

Knowledge graphs are a tool of the information age in which we all now find ourself. As we transition from an industrial economy into a digital economy during this fourth industrial revolution[299]; the tools we use need to change to be updated for the current times.

What exactly is a knowledge graph[300]? At the core of every machine-readable knowledge graph is a machine-readable knowledge model. A knowledge model is a collection of interlinked logical statements that describe the terms, structures, associations, rules, and facts that make up that knowledge graph. Knowledge graphs put information into context via linking and logical oriented metadata and this way provide a framework for data integration, solving problems, information analysis and sharing of that machine-readable information.

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[295] Knowledge Graph of Microsoft 10-K Financial Report, http://xbrl.squarespace.com/journal/2021/7/12/knowledge-graph-of-microsoft-10-k-financial-report.html

[296] Effective Automation of Record to Report (Iteration #4), http://xbrl.squarespace.com/journal/2021/1/25/effective-automation-of-record-to-report-process-iteration-4.html

[297] Digital Distributed Ledgers, http://www.xbrlsite.com/mastering/Part01_Chapter02.J_DistributedLedgers.pdf

[298] Mastering XBRL-based Digital Financial Reporting, http://xbrl.squarespace.com/mastering-xbrl/

[299] *Adapting to Changes Caused by the Fourth Industrial Revolution*, http://xbrl.squarespace.com/journal/2019/8/4/adapting-to-changes-caused-by-the-fourth-industrial-revoluti.html

[300] Ontotext, *What is a Knowledge Graph?*, https://www.ontotext.com/knowledgehub/fundamentals/what-is-a-knowledge-graph/

Financial reports are knowledge graphs.

When you try and understand knowledge graphs you often tend to run across explanations in terms of products that are offered. Three excellent resources that explain knowledge graphs in terms of specific product implementations include:

- *The Knowledge Graph Cookbook: Recipes that Work*[301] (uses the W3C standard Semantic Web Stack; this approach uses RDF, SWRL, OWL, N3, SHACL, SPARQL, and other such W3C standard technologies for representing data, ontologies, and rules[302])
- *Graph Databases*[303] (uses the Neo4j graph database and graph compute engine, which will very likely become an ISO standard graph query language[304])
- *Systematic Introduction to Expert Systems*[305]*: Knowledge Representation and Problem-Solving Methods* (uses programming logic, PROLOG, for which is an ISO standard[306])

A significant portion of the information in this resource comes from those three excellent resources. If you want additional details after reading this document, those three books are worth looking into. Those three resources provide information about implementing knowledge graphs within specific software applications.

Either of these three problem solving logic paradigms[307] can be employed effectively to represent financial reports. Further, the global standard XBRL[308] technical syntax can be bi-directionally serialized into or out of any of these three paradigms.

A financial report is a knowledge graph. I will explain what I mean by that in this document. A financial report is also a type of logical system and a specialization of a business report. You could interact with financial report knowledge graphs using general-purpose tools for processing any knowledge graphs.

But there are significant advantages to using special-purpose tools, tuned specifically for financial report knowledge graphs, when you want to interact with a financial report knowledge graph. These special-purpose tools are easier for business professionals to use and offer all the power of a general-purpose tool such as a graph database and a graph compute engine.

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[301] *The Knowledge Graph Cookbook: Recipes that Work*, http://xbrl.squarespace.com/journal/2021/6/27/the-knowledge-graph-cookbook-recipes-that-work.html
[302] W3C, *Semantic Web*, https://www.w3.org/2001/sw/wiki/Main_Page
[303] *Graph Databases*, https://neo4j.com/neoassets/graphbooks/Graph_Databases_2e_Neo4j.pdf
[304] *New Query Language for Graph Databases to Become International Standard*, https://neo4j.com/press-releases/query-language-graph-databases-international-standard/
[305] Frank Puppe, *Systematic Introduction to Expert Systems: Knowledge Representation and Problem-Solving Methods*, https://www.google.com/books/edition/_/_kKqCAAAQBAJ
[306] ISO, *ISO/IEC 13211-1:1995 Information technology — Programming languages — Prolog — Part 1: General core*, https://www.iso.org/standard/21413.html
[307] Implementing Knowledge Graphs, http://xbrl.squarespace.com/journal/2021/9/20/implementing-knowledge-graphs.html
[308] XBRL International, *XBRL Standard*, https://www.xbrl.org/the-standard/

To create a specialized logical conceptualization of a financial report from a general logical conceptualization of a knowledge graph we use three steps:

1. Logical theory or logical system
2. Logical conceptualization of a business report which builds on and is a type of logical theory.
3. Logical conceptualization of a financial report which builds on but is a type of business report.

The logical conceptualization of a financial report is knowledge that can be stored in the form of a graph. As such, a financial report is a knowledge graph.

All this will be explained in this resource. Let's start by breaking down the terms "knowledge" and "graph".

5.1. Overview

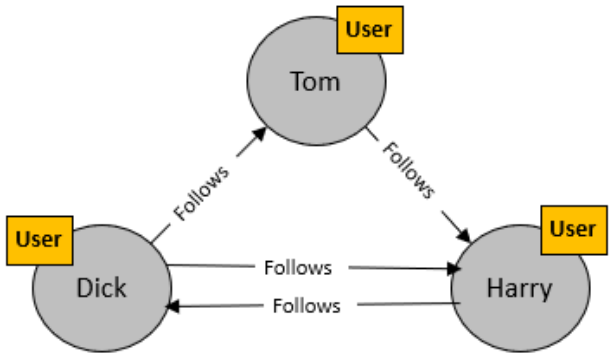
We communicate using knowledge graphs. When you go to a whiteboard and draw circles and squares and connect them with lines with arrows you are drawing a graph and communicating knowledge. Those circles, squares, lines, and arrows are intuitively understandable and very expressive. These informal knowledge graphs like this have been used by humans to communicate information for quite some time.

Knowledge is the understanding or interpretation of information. Knowledge relates to terms, structures, associations, rules, facts, and skills acquired by a person through experience or education that relates to the theoretical or practical understanding of something.

A **graph**, in formal terms, is a set of vertices and edges. In less intimidating language, a graph is a set of nodes and the relationships that connect the nodes together. Graphs represent things as nodes and the ways in which those things relate to one another and rest of the world as relationships.

A graph is a general-purpose communications tool that allows us to model all sorts of scenarios in terms that are innately understandable to humans. One thing that can be represented in the form of a graph is knowledge.

This is a simple graph of knowledge, or a **knowledge graph**:



A knowledge graph[309], also known as a semantic network, represents a network of real-world things (entities)—i.e. objects, events, situations, or concepts—and illustrates the relationship between them. This information can be visualized as a graph structure.

Knowledge graphs are rich in terms of expressiveness but still innately understandable by humans but knowledge graphs can also be read and understood by machines such as computers.

A general-purpose **financial report** conveys knowledge about the financial status, financial performance, and liquidity of an economic entity. For example, here is a fragment of a financial report:

Statement [Line Items]	Period [Axis]		
	2016-07-01 - 2017-06-30	2015-07-01 - 2016-06-30	2014-07-01 - 2015-06-30
Net income	21,204,000,000 [2,3]	16,798,000,000 [1]	12,193,000,000
Other comprehensive income (loss):			
Net unrealized gains (losses) on derivatives (net of tax effects of $(5), $(12), and $20)	(218,000,000)	(238,000,000)	559,000,000
Net unrealized losses on investments (net of tax effects of $(613), $(121), and $(197))	(1,116,000,000)	(228,000,000)	(362,000,000)
Translation adjustments and other (net of tax effects of $9, $(33), and $16)	228,000,000	(519,000,000)	(1,383,000,000)
Other comprehensive loss	(1,106,000,000)	(985,000,000)	(1,186,000,000)
Comprehensive income	20,098,000,000	15,813,000,000	11,007,000,000

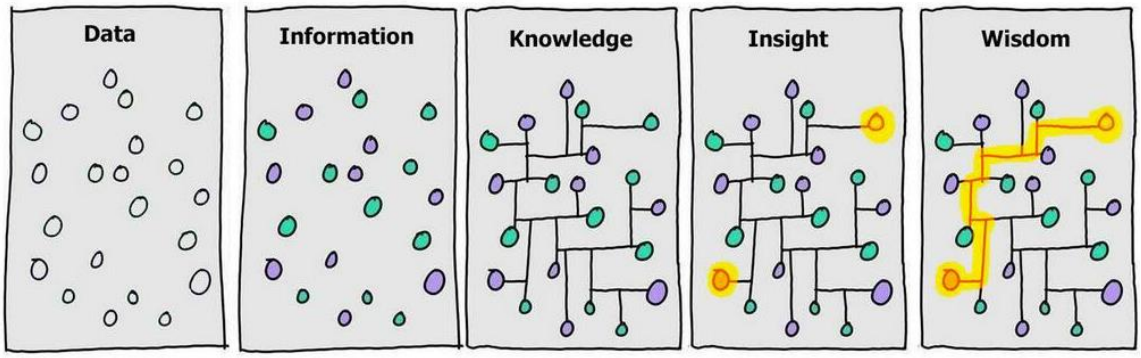
The information contained within a financial report can also be seen as or represented as a knowledge graph that is readable by both machines and by humans. While the formatting of the information within a financial report is different than the formal vertices and edges of a graph; I think that it is rather easy to see or perceive that a financial report is a knowledge graph.

Let's start to expand on our understanding of knowledge graphs by looking at two terms: knowledge and graph.

5.2. Knowledge

The following graphic perhaps provides the best visual explanation as to the difference between data, information, knowledge, insight, and wisdom[310] that I have run across:

[309] IBM, *What is a Knowledge Graph?*, https://www.ibm.com/topics/knowledge-graph
[310] Tumblr, *Information isn't Power*, https://random-blather.com/2014/04/28/information-isnt-power/



There are specific differences between data, information, knowledge, insight, and wisdom[311]:

- **Data**: The basic compound for intelligence is data. Data are measures, observations, symbols, phenomenon, utterances, and other such representations of the world around us presented as external signals and picked up by various sensory instruments and organs. *Simplified: data is raw facts and numbers*.
- **Information**: Information is produced by assigning relevant meaning related to the context of the data to the data. *Simplified: information is data in context*.
- **Knowledge**: Knowledge is the understanding or interpretation, a justifiable true belief, of information and approach to act upon the information in the mind of the perceiver. *Simplified: knowledge is the interpretation of information*.
- **Insight**: Insight is the first step in putting information and knowledge to work for you.
- **Wisdom**: Wisdom embodies awareness, insight, moral judgments, and principles to construct new knowledge and improve upon existing understanding. *Simplified: wisdom is the creation of new knowledge*.

The difference between *data* and *information* is that data is the raw numbers and words where information is data in context. This is important to understand as most problems faced by accountants are an information problem, rather than a data problem. Getting data is easy. Knowing what that data represents and how the data fits together is more difficult. Representing information in the form that a machine such as a computer can understand and use that information safely and effectively is difficult.

Knowledge is a set of data and information and a combination of skill, know-how, experience which can be used to improve the capacity to take action or support a decision making process.

Insight and wisdom are related to putting information and knowledge to work for you.

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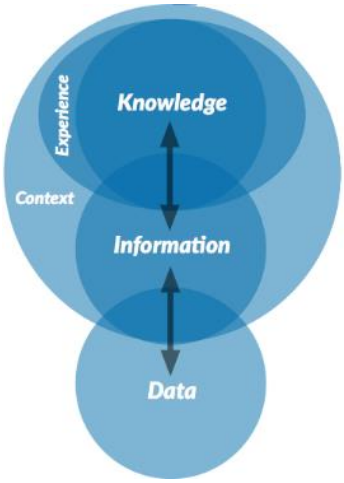
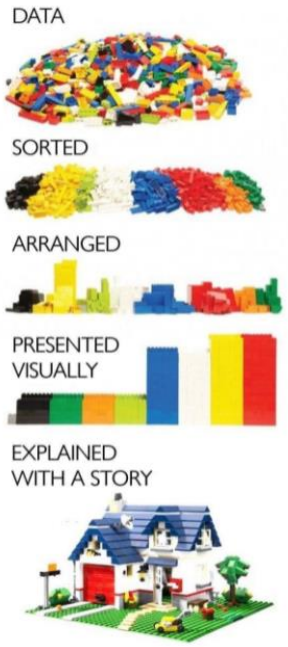
[311] Wikipedia, *DIKW Pyramid*, retrieved February 24, 2016, https://en.wikipedia.org/wiki/DIKW_Pyramid

The following graph created by Shawn Riley shows the important to understand differences between data, information, and knowledge[312].



The important point to understand here is that it takes the skill and experience of human professionals to create information and knowledge and put that knowledge into the proper context.

Another very interesting graphic posted by Mark Cossey[313] is this which shows the value and therefore power of classification[314]:

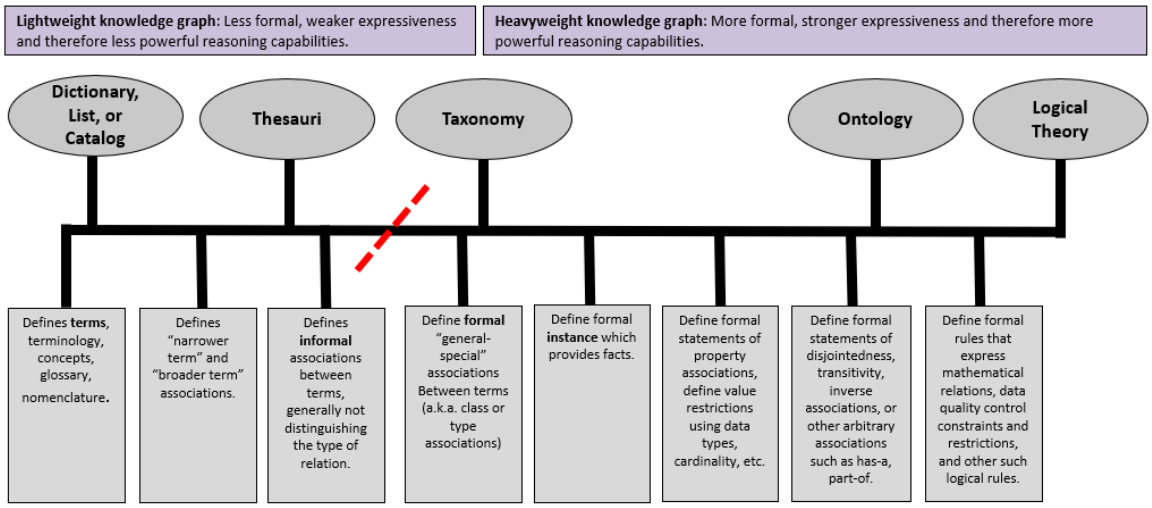


[312] Shawn Riley, *Machine Learning versus Machine Understanding*, https://www.linkedin.com/pulse/machine-learning-vs-understanding-shawn-riley/
[313] LinkedIn, Mark Cossey, https://www.linkedin.com/feed/update/urn:li:activity:6839928291433029632/
[314] *Understanding the Power of Classification*, http://xbrl.squarespace.com/journal/2019/5/14/understanding-the-power-of-classification.html

The point that I am trying to make is that there is a very significant difference between data, information, and knowledge. Or focus is on information and knowledge, not data.

5.3. Knowledge Representation Approaches

There are a number of different tools that can be used to effectively represent knowledge. Below you see a spectrum of such tools with the least powerful tools on the left and increasing in power to the right:



Inspired primarily by Deborah L. McGuinness, *Ontologies for the Modern Age,* Slide 4, https://www.slideshare.net/deborahmcguinness/ontologies-for-the-modern-age-mcguinness-keynote-at-iswc-2017

When representing knowledge, the right tool should be used for the job. A logical theory is the easiest way to enable business professionals to understand a logical system because business professionals have an innate understanding of logic. When representing the logic of a financial report, the power of a logical theory is necessary.

5.4. Graphs

When I use the term graph, I am referring to the term in the context of graph theory[315] which is a discipline of mathematics. Wikipedia's definition of graph theory and graph is:

In mathematics, graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects.

This is a very simple graph:

Just like most other things, graphs have a jargon. In formal graph jargon, the circles are referred to as **edge** and the line is referred to as a **vertex**.

[315] Wikipedia, *Graph Theory*, https://en.wikipedia.org/wiki/Graph_theory

Others in other areas use different terminology to refer to exactly the same idea. Here are synonyms for the notions of *edge* and *vertex*:

Edge	Entity	Node	Point	Report element
Vertex	Relationship	Line	Path	Association

Reconciling this to something you might know from grammar[316],

- **Noun**: naming words; person, place, or thing. (represented as an edge)
- **Verb**: doing words; action or doing (represented as a vertex)
- **Adjective**: describes a noun (property of an edge)
- **Adverb**: describes a verb (property of a vertex)

A graph can have can have one or more paths between points; paths can have loops or cycles, circuits, as well as can have self-loops, and paths can go in one direction or both directions.

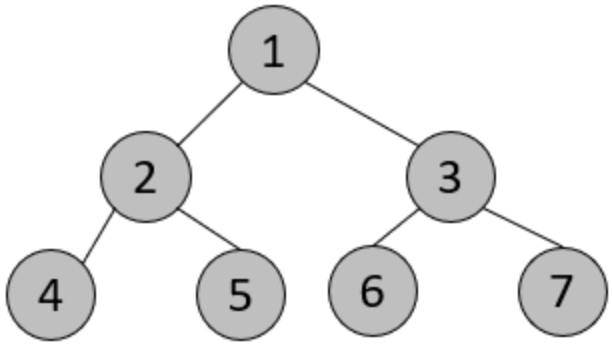
To better understand graphs, let's look at some subtle but very important differences between some different types of graphs.

If we take the time to consciously formalize the rules related to graphs and understand those rules these communications tools become more effective and they can even be understood by computer software applications.

5.5. Trees

A **tree** is a special type of graph. Most people are more familiar with trees than graphs. A tree is what is called an undirected graph because the items in a tree are connected by exactly one path. This is important to understand because it means that trees are safer than other types of graphs which can contain cycles. But trees have a limitation in that an edge can appear only once in a tree and a tree always has exactly one root edge. Also, because trees are undirected, they provide less information and so they are less powerful in terms of expressiveness.

The following is an example of a graph that is also a tree:

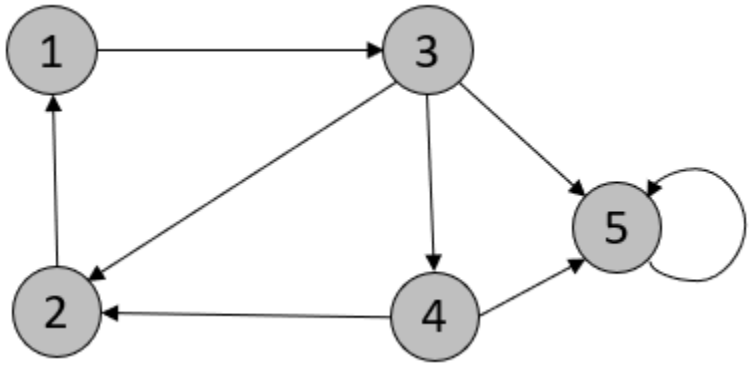


316 Teaching Resource, https://www.teachstarter.com/au/teaching-resource/nouns-verbs-adjectives-adverbs-posters/

Notice the root, node number 1 and that ever other node that appears is unique. Notice also that there is no direction associated with the lines that appear between the nodes.

5.6. Directed Graph

A **directed graph** is a special type of graph that provides a direction on each vertex. For example, below you see a directed graph:

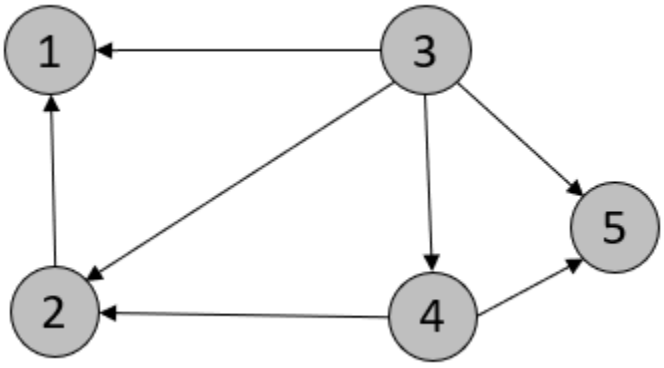


Note that each vertex (line) has an arrow that points in a specific direction; that is what makes the graph a directed graph. Note edge (node) number 5 which has an arrow that points to itself; that is a cycle. Cycles like that can cause issues such as causing an infinite loop. Those sorts of issues can be solved by using a directed acyclic graph that does not allow such cycles which we will cover next.

Directed graphs are more powerful than trees but because of the possibility of a cycles, they can be unsafe for certain things.

5.7. Directed Acyclic Graph

A **directed acyclic graph** (DAG) is an even more special type of graph that provides a direction on each vertex and you are guaranteed not to have any cycles in the graph. This makes the graph very save as there is not a possibility of creating infinite loops that can break software applications. For example, below you see a directed acyclic graph:



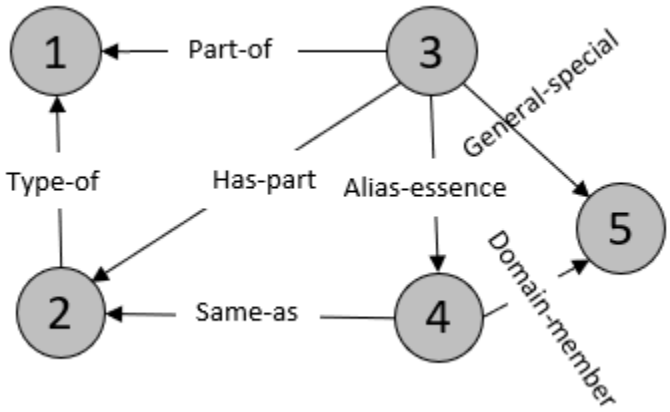
Note again that each vertex has an arrow which specifies a direction and that there are no cycles making this a directed acyclic graph. Note that there is not one specific edge (node) that can be considered the root of the graph.

But note that you don't have any information about the nature of the vertices (lines). What if information was provided about the relationships in the graph as communicated by the vertices (lines)?

5.8. Labeled Directed Acyclic Property Graph

A **labeled directed acyclic property graph** specifies a type of vertex for each association between any two edges. Specifying that feature, the nature of the relationship, provides additional information that is useful in working with a graph.

For example, below you see a labeled directed acyclic graph:



Note the labels that explain each vertex in the graph. You can, for example, query a graph for those relationship types. Labeled directed acyclic graphs have the most power in terms of expressiveness but are also very safe to use because they are guaranteed not to contain any cycles which can lead to catastrophic failure when read by a machine-based process.

5.9. Typed Directed Acyclic Property Graph

Now I am getting over my head, but this seems to have a profoundly important impact on functionality and query speed. There seems to be a difference between a "labeled property graph" and a "typed property graph". Also, there seems to be a critically important difference between RDF graphs and graph databases. Seems that RDF graphs are typed, but you cannot add properties. Seems that labeled property graphs are more flexibly, but that flexibility might not be needed and it impacts functionality and query speed.

This is maddeningly difficult for a business professional to understand. But, reading this article *Labeled vs Typed Property Graphs — All Graph Databases are not the same*[317] and understanding TypeDB[318] are important. Strongly typed graph

[317] Medium, *Labeled vs Typed Property Graphs — All Graph Databases are not the same*, https://medium.com/geekculture/labeled-vs-typed-property-graphs-all-graph-databases-are-not-the-same-efdbc782f099
[318] Vaticle, Strongly Typed Database, https://vaticle.com/

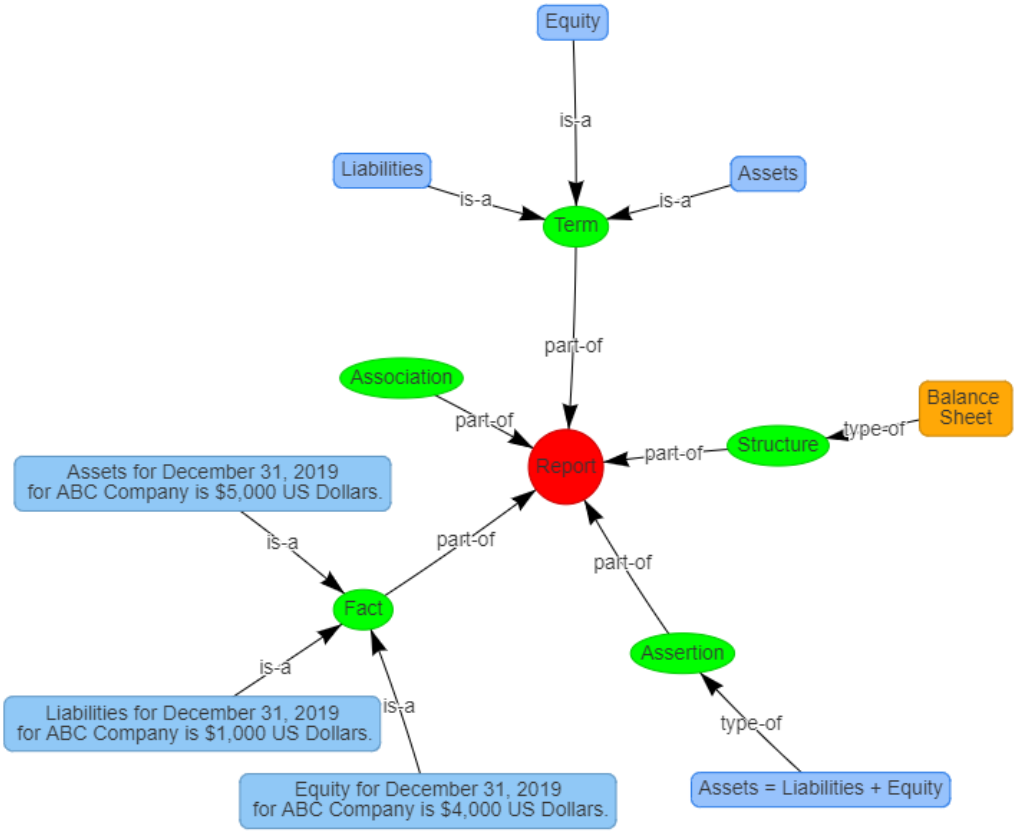
databases seem very compelling. "TypeDB provides a strong type system for developers to break down complex problems into meaningful and logical systems. Through TypeQL, TypeDB provides powerful abstractions over low-level and complex data patterns."

This seems like incredibly important stuff but I don't really understand it as well as I would like to. And frankly, most software engineers don't seem to understand it well either which makes this problematic. Finally, how does something like PROLOG fit into this comparison.

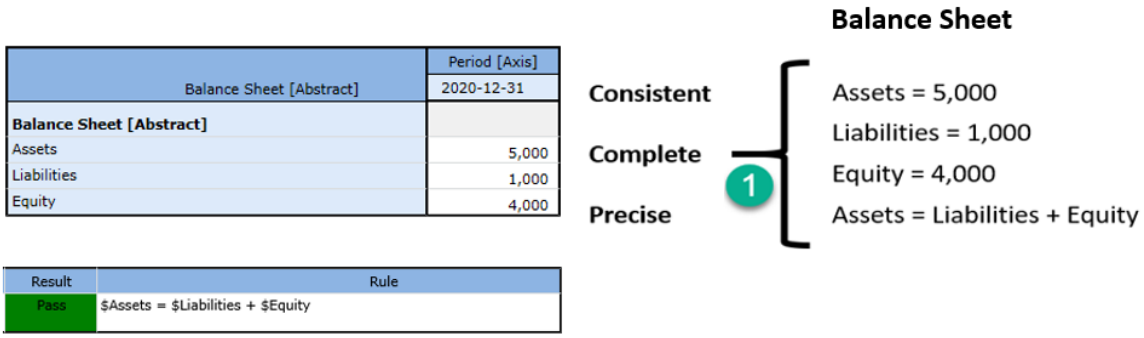
5.10. Visualizing Graph of Knowledge

The precise visualizations provided by software tools that implement a graph of knowledge can be different. Colors can be used to enhance visualizations. Different shapes can be used for showing edges (nodes). Visualizations might be laid out in a variety of different ways. There is not necessarily one standard visualization.

Here is information related to the accounting equation and three facts reported within that report model represented in the form of a labeled directed acyclic graph:



Here is that same information presented in a manner that might be more familiar to professional accountants:



Balance Sheet [Abstract]	Period [Axis] 2020-12-31
Balance Sheet [Abstract]	
Assets	5,000
Liabilities	1,000
Equity	4,000

Balance Sheet

Consistent
Complete
Precise
1

Assets = 5,000
Liabilities = 1,000
Equity = 4,000
Assets = Liabilities + Equity

Result	Rule
Pass	$Assets = $Liabilities + $Equity

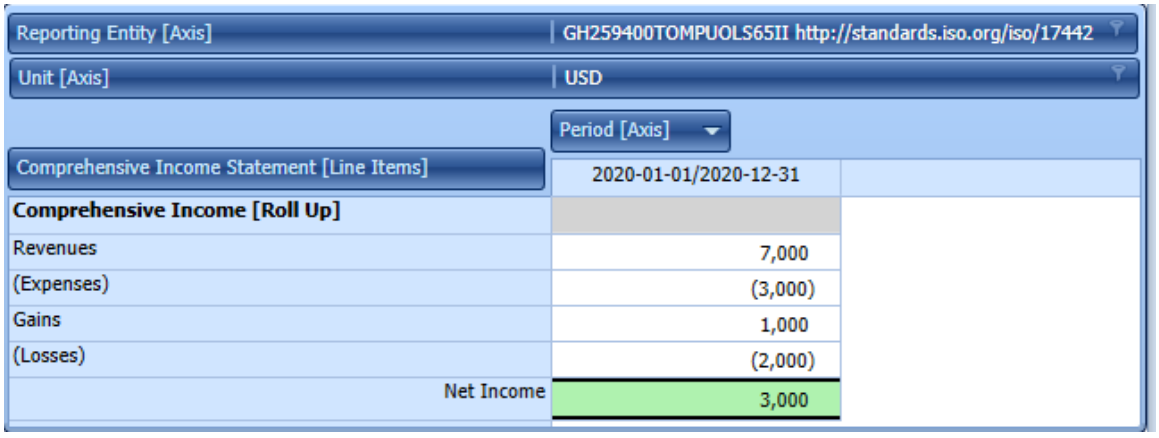
5.11. Special-purpose Knowledge Graph

Knowledge graphs are general-purpose tools that can be modified and turned into special-purpose tools by adding a specific logical model that both constraints and controls the functionality of the general-purpose model.

Converting from a general-purpose tool to a special-purpose tool has two consequences. First, special-purpose tools are less functional and less flexibly than general-purpose tools. Secondly, special-purpose tools are an order of magnitude easier to use that a general-purpose tool.

If you give up flexibility that you don't need then you lose nothing but you gain ease of use. That is the benefit of creating special-purpose tools.

This is what a special-purpose financial report knowledge graph might look like:



Reporting Entity [Axis]	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442
Unit [Axis]	USD

Comprehensive Income Statement [Line Items]	Period [Axis] 2020-01-01/2020-12-31
Comprehensive Income [Roll Up]	
Revenues	7,000
(Expenses)	(3,000)
Gains	1,000
(Losses)	(2,000)
Net Income	3,000

Label	Report Element Class	Period	Balance	Preferred Label Role	Name
Comprehensive Income Statement [Hypercube]	[Table]			Standard Label	proof:ComprehensiveIncomeStatementHypercube
Comprehensive Income Statement [Line Items]	[LineItems]			Standard Label	proof:ComprehensiveIncomeStatementLineItems
Comprehensive Income [Roll Up]	[Abstract]			Standard Label	proof:ComprehensiveIncomeRollUp
Revenues	[Concept] Monetary	For Period	Credit	Standard Label	proof:Revenues
(Expenses)	[Concept] Monetary	For Period	Debit	Negated Label	proof:Expenses
Gains	[Concept] Monetary	For Period	Credit	Standard Label	proof:Gains
(Losses)	[Concept] Monetary	For Period	Debit	Negated Label	proof:Losses
Net Income	[Concept] Monetary	For Period	Credit	Standard Label	proof:NetIncome

#	Reporting Entity	Period	Concept	Fact Value	Unit	Rounding	Parenthetical Explanations
1	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442	2020-01-01/2020-12-31	Revenues	7000	USD	0	
2	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442	2020-01-01/2020-12-31	(Expenses)	3000	USD	0	
3	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442	2020-01-01/2020-12-31	Gains	1000	USD	0	
4	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442	2020-01-01/2020-12-31	(Losses)	2000	USD	0	
5	GH259400TOMPUOLS65II http://standards.iso.org/iso/17442	2020-01-01/2020-12-31	Net Income	3000	USD	0	

Label	Rendered Value	Op	Reported Value	Calculated Value	Balance	Result	Name
Comprehensive Income Statement [Line Items]							proof:ComprehensiveIncomeStatementLineItems
Comprehensive Income [Roll Up]							proof:ComprehensiveIncomeRollUp
Revenues	7,000	+	7,000		Credit		proof:Revenues
(Expenses)	(3,000)	-	3,000		Debit		proof:Expenses
Gains	1,000	+	1,000		Credit		proof:Gains
(Losses)	(2,000)	-	2,000		Debit		proof:Losses
Net Income	3,000		3,000	3,000	Credit	Verified	proof:NetIncome

Can you see the knowledge graph in the different representations of information? Think dynamic pivot table.

Next, let us apply the general ideas of a knowledge graph to financial reports.

5.12. Control

Financial reports tell a story. That story is about the financial position and financial performance of a reporting economic entity. That story must be "true" and "fair". That story is a "signal" your organization sends.

The information conveyed by that story (contained in that signal) should be the same whether a traditional human readable report is used as the medium or whether a machine readable knowledge graph is used as the medium.

Financial reports are not "standard forms". Report models can be modified or "customized" by reporting entities which can use different "subtotals", different disclosure "alternatives", and even report additional disclosures which the economic entity feels is important to understanding that specific economic entity. That flexibility is a feature of financial reporting schemes such as US GAAP and IFRS.

But while financial reports are not "standard forms", they are also not "random". There are patterns. There are "good practices" and "best practices".

When a report model can be modified/customized, the "wild behavior" of accountants creating reports and report models must be controlled and preferably even eliminated, keeping report models within permitted boundaries. While permitted boundaries can be defined differently by, say, different CPA firms or even different accountants within the same CPA firm; patterns exist and those patterns can be leveraged.

A financial reporting scheme represented using an XBRL taxonomy which is then used to represent a report model for a report created by an economic entity in machine readable form serves multiple purposes:

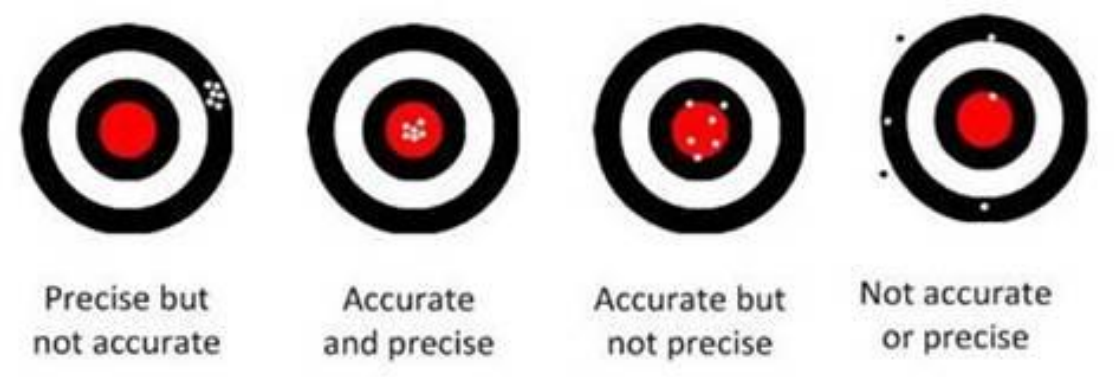
- **Description**: It is a clear and should be complete description of a report model (specification of what is permitted); created by standards setters or regulators or anyone else specifying a report. And obviously the clear and complete description should represent accounting and reporting rules precisely and accurately.
- **Construction**: It is a guide to the creation of a report based on that permitted report model description whereby a human can be assisted by

software applications utilizing that machine readable description of permitted report models.

- **Verification**: The actual report constructed can be verified against the clear, complete description assisted by software applications utilizing that machine readable description.
- **Extraction**: Information can be effectively extracted from machine readable reports and report models assisted by software utilizing that machine readable clear and complete description.

Note that the machine readable version of the report model description and report can be automatically converted from the machine readable format to a human readable format using automated processes.

To reiterate; a machine readable representation of a financial reporting scheme in an XBRL taxonomy must be ***clear***, ***complete***, and reflect accounting and reporting rules ***precisely*** and ***accurately***[319].



Traditionally, financial reporting schemes have been represented in books and can often be unclear. The US GAAP and IFRS XBRL taxonomies are, as they are represented today, are not clear as the really could be or need to be, they are not complete, they are missing rules.

Further, US GAAP and IFRS reporting rules are sometimes ambiguous, but that lack of clarity can be "worked around" by a skilled and experienced accountant that understands accounting and reporting principles and the existing rules well and if they have the right skill and experience they can create "sensible" alternatives considering the ambiguous (i.e. not clear) articulation of the rules by standards setters and regulators.

Whether accounting and reporting rules are in human readable form or machine readable form; these knowledge graphs should be clear, complete, accurate, and precise. The advantage of machine readable form is that the process can be more formalized and tasks and processes can be automated.

5.13. Graphs vs Relational Databases

In his paper, *At Its Core: How Is a Graph Database Different from a Relational One?*[320], Philipp Brunenberg summarizes the fundamental difference between graph

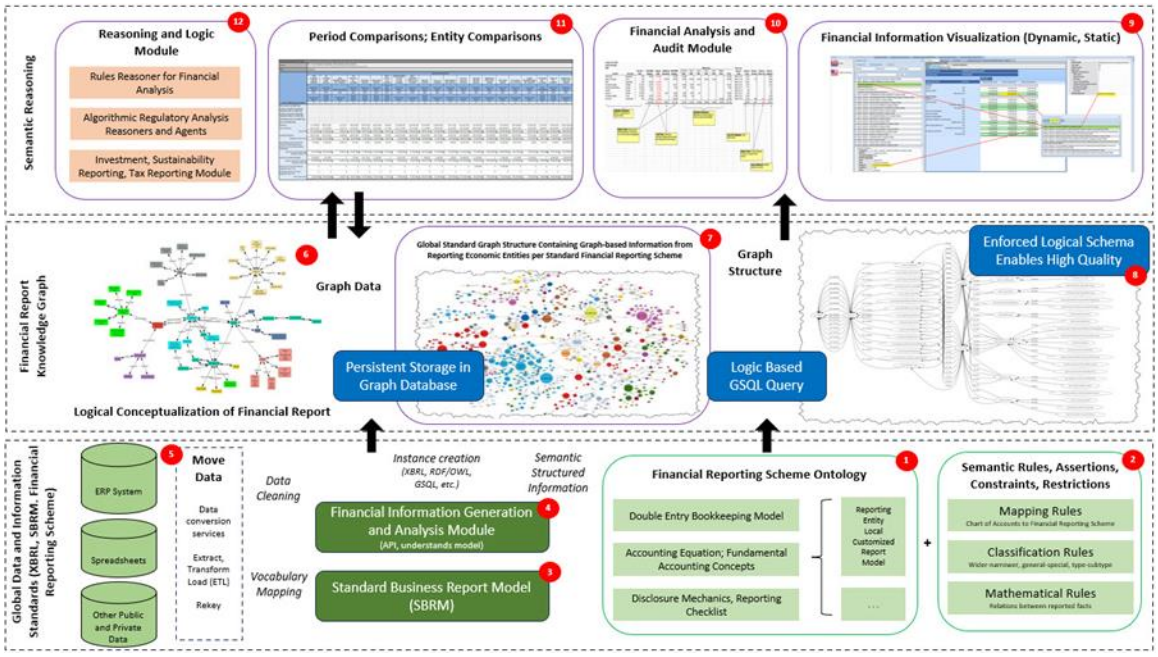
[319] What is Accuracy?, https://www.adamequipment.com/aeblog/what-is-accuracy

databases and relational databases: "Graph and relational databases differ in one fundamental design principle: Graphs do have a concept of a relationship and relational don't. That's why a graph database can manage interconnected data much more efficiently. Still, both have their reasons for existence: Graphs perform better and are more intuitive to use when analyzing an entire context close to a single data point — potentially with multiple hops. However, if the exploration of highly joined and densely connected data is not a requirement, a relational model may serve the needs similarly well."

In the hands of someone with no skills or experience working with knowledge graphs; they tend to produce clumsy, ugly, barely functional output. But in the hands of a skilled craftsmen, knowledge graphs can produce works of utility, elegance, beauty, and durability.

5.14. Knowledge Graph System

As best as I can understand it and describe it, what will exist in the future is a knowledge graph system[321] for financial reporting. This is a graphic of the components of the big picture as I see it, a knowledge graph system for financial reporting[322]:



Such a knowledge graph system is made up of knowledge assemblies.

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[320] Philipp Brunenberg, *At Its Core: How Is a Graph Database Different from a Relational One*?, https://towardsdatascience.com/at-its-core-hows-a-graph-database-different-from-a-relational-8297ca99cb8f

[321] *Knowledge Graph System*, https://digitalfinancialreporting.blogspot.com/2023/07/knowledge-graph-system.html

[322] *Knowledge Graph System for Financial Reporting*, https://digitalfinancialreporting.blogspot.com/2023/07/knowledge-graph-system-for-financial.html

This article published by the IEEE, *EHR-Oriented Knowledge Graph System: Toward Efficient Utilization of Non-Used Information Buried in Routine Clinical Practice*[323], uses the term "knowledge graph system" and others have used the term "knowledge graph approach" to describe what I am trying to achieve using the *Seattle Method*.

The vision provided by that article for electronic health records is similar to what I am trying to achieve for financial reporting.

5.15. Knowledge Assembly

A knowledge assembly[324] is a set of knowledge graphs. A knowledge graph is a machine-readable structured representation of knowledge (semantics) related to a particular area of interest. So, a knowledge assembly is a machine-readable network of things and relations between things. The things and relations are classified or grouped in helpful/useful ways. Semantics is the science of giving meaning to data. Knowledge assemblies are about semantics which is data in context, a.k.a. information. Knowledge = ontology (things and relations between things) + rules (assertions, restrictions, constraints). A knowledge assembly can be explained using a logical theory or logical schema that verifies/validates the knowledge assembly. Knowledge assembly terminology is grounded in the more approachable and innately understandable terminology of logic and philosophy, not the technical jargon/terminology of computer science.

I ran across a new term, knowledge assembly[325], which is used to explain some important ideas related to the idea of a knowledge graph or knowledge graph system. Similar terms are knowledge fabric[326] or data fabric or data mesh or information mesh. Allow me to explain.

Hetionet[327] provides an example of what they refer to as a knowledge assembly. Hetionet is a demonstration of connecting multiple databases of information (an "assembly") that contain data and meta data related to biomedicine.

A similar sort of knowledge assembly for a financial reporting scheme which is a subset of finance. There is knowledge that is common to all financial reporting schemes such as the double entry bookkeeping model and the accounting equation. The logical model of a financial report is part of that assembly. The conceptual framework of the financial reporting scheme is a part of the knowledge assembly. The different reporting styles permitted by that financial reporting scheme is part of the knowledge assembly. How to compute financial ratios used to analyze information reported per that scheme are part of the knowledge assembly. A specific economic entity's report model is another part of the assembly. The entire SEC EDGAR system database of reports could be part of the knowledge assembly, or similarly the ESMA database of reported financial information.is another part of the assembly.

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[323] IEEE, *EHR-Oriented Knowledge Graph System: Toward Efficient Utilization of Non-Used Information Buried in Routine Clinical Practice*, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9444689

[324] *Knowledge Assembly*, https://digitalfinancialreporting.blogspot.com/2023/08/knowledge-assembly.html

[325] Knowledge Assembly, https://digitalfinancialreporting.blogspot.com/2023/08/knowledge-assembly.html

[326] Knowledge Fabric, https://youtu.be/yNsE02FAR3w?si=_VbcDy40u_nN9HUb

[327] Hetionet, https://het.io/

5.16. Global Standard Knowledge Assembly

My PROOF[328] (and my other examples[329]) provides examples of a global standard XBRL-based knowledge assembly[330] of a financial reporting scheme, a financial report model created by a reporting economic entity using that financial reporting scheme, and a financial report using that financial report model that is based on the financial reporting scheme. That entire knowledge assembly is validated using a rules engine that is specialized for this specific type of knowledge assembly to verify that the report and report model are complete, consistent, and precise. This mechanism is described by the Seattle Method.

That knowledge assembly contains data and meta data related to financial accounting and financial reporting. The physical syntax of the entire knowledge assembly is global standard XBRL. The XBRL technical syntax is used to define logical terms, structures, associations, assertions, restrictions, constraints, and facts.

The logical model of a financial report is part of that assembly. Key portions of the conceptual framework of a financial reporting scheme is a part of the knowledge assembly. The different reporting styles permitted by that financial reporting scheme is part of the knowledge assembly. Wider-narrower (a.k.a. type-subtype or general-special) relations are part of the knowledge assembly. Fundamental accounting relations that are universal to a specific reporting style is part of the knowledge assembly. How to compute financial ratios used to analyze financial information reported per that financial reporting scheme are part of the knowledge assembly. Rules are declarative in nature.

6. Financial Report Knowledge Graph

In the previous section we summarized the general ideas related to knowledge graphs. We pointed out that a graph is a very expressive communications tool and one thing that can be communicated using a graph is knowledge.

In this section we apply those general ideas to the specific use case of financial reports.

There are no natural representations of the world the way it "really is," just many purposeful selections, abstractions, and simplifications, some of which are more useful than others for satisfying a particular goal.

Financial reports are knowledge graphs of the logic conveyed by the information within the financial report. A problem arises when a knowledge graph of a financial report is less capable masquerades as more capable or fully capable knowledge graph of meaning. Professional accountants and auditors need to be able to tell the difference between the two.

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[328] *PROOF Financial Reporting Scheme* (Prototype), http://www.xbrlsite.com/seattlemethod/platinum/proof/base-taxonomy/proof_ModelStructure.html

[329] *PLATINUM XBRL-based Financial Report Examples*, https://digitalfinancialreporting.blogspot.com/2023/07/platinum-xbrl-based-financial-report.html

[330] *Global Standard Knowledge Assembly*, https://digitalfinancialreporting.blogspot.com/2023/08/global-standard-knowledge-assembly.html

A financial report tells a story. That story is a signal conveyed to regulators, investors, or others. The human readable and machine readable versions of that story should be the same. The machine readable version of the story should be saying the same thing as the human readable version.

6.1. General-purpose Financial Report

A general-purpose financial report is a true and fair representation of information about an economic entity. A financial report is not the actual economic entity, it merely conveys fairly high-fidelity information about an economic entity that is generally of very high-quality. Consider the following use case of a general-purpose financial report:

Two economic entities, A and B, each have information about their financial position and financial performance. They must communicate their information to an investor who is making investment decisions which will make use of the combined information so as to draw some conclusions. All three parties (economic entity A, economic entity B, investor) are using a common set of basic logical principles (facts, statements, deductive reasoning, inductive reasoning, etc.), common financial reporting standard concepts and relations (i.e. US GAAP, UK GAAP, IFRS, IPSAS, etc.), and a common world view so they should be able to communicate this information fully, so that any inferences which, say, the investor draws from economic entity A's information should also be derivable by economic entity A itself using basic logical principles, common financial reporting standards (concepts and relations), and common world view; and vice versa; and similarly for the investor and economic entity B.

There is no natural way to represent an economic entity the way it "really is" in the real world; there are just certain purposeful selections of specific aspects of an economic entity, call them abstractions or models, that provide a useful enough simplification that satisfies some specific goal we might have. That is the nature of a general-purpose financial report, to represent information about an economic entity for a specific purpose. That representation is good enough to be useful.

Financial report knowledge graphs can be interrogated systematically and logically using machine-based processes.

A general-purpose financial report is a high-fidelity, high-resolution, high-quality information exchange mechanism. The report is a compendium of complex logical information required by statutory requirements and regulatory rules plus whatever management of an economic entity wants to voluntarily disclose. The report represents quantitative and qualitative information about the financial condition and financial performance of an economic entity. There are a number of different financial reporting schemes that might be used to create a general-purpose financial report such as US GAAP, IFRS, IPSAS, GAS, FAS, etc.[331].

Financial reports are not uniform[332]. Financial reports are not forms; they have variability. This consciously allowed variability is an essential, characteristic trait of robust reporting schemes such as US GAAP, IFRS, and others. This allowed variability contributes to the richness, high-fidelity, and high-resolution of reported

[331] *Financial Reporting Schemes*, http://xbrlsite.azurewebsites.net/2020/master/ElementsOfFinancialStatements.pdf
[332] *Essence of Accounting*, http://xbrlsite.azurewebsites.net/2020/Library/EssenceOfAccounting.pdf

financial information that is unique to an industry sector, a style of reporting, or an economic entity. This variability is a feature of such reporting schemes. Different reporting styles, different subtotals used to aggregate details, and using some specific approach given a set of allowed alternatives are examples of variability. Variability does not mean "arbitrary" or "random". There are known identifiable patterns.

Rules are used to articulate allowed variability and "channel" creators of financial reports in the right direction and therefore control variability, keeping the variability within standard limits. That keeps quality where it needs to be. Rules enable things like preventing a user from using a concept meant to represent one thing from unintentionally being used to represent something different.

Further, the discipline of describing something in a form a computer algorithm can understand also assists you in understanding the world better; weeding out flaws in your understanding, myths, and misconceptions about accounting and reporting standards.

6.2. Economic Entity Report Model

Because each financial report can be different, each financial report created by each economic entity essentially has its own specific report model. However, all financial reports fit into one financial report metamodel that is described by the *Logical Theory Describing Financial Report*[333].

It is that logical conceptualization of a financial report that turns a general-purpose knowledge graph into a special-purpose knowledge graph. To use this special-purpose knowledge graph, professional accountants need only understand the fundamentals of knowledge graphs, understand the logic of a financial report, and understand the financial report metamodel which is used to create all financial report models for every economic entity.

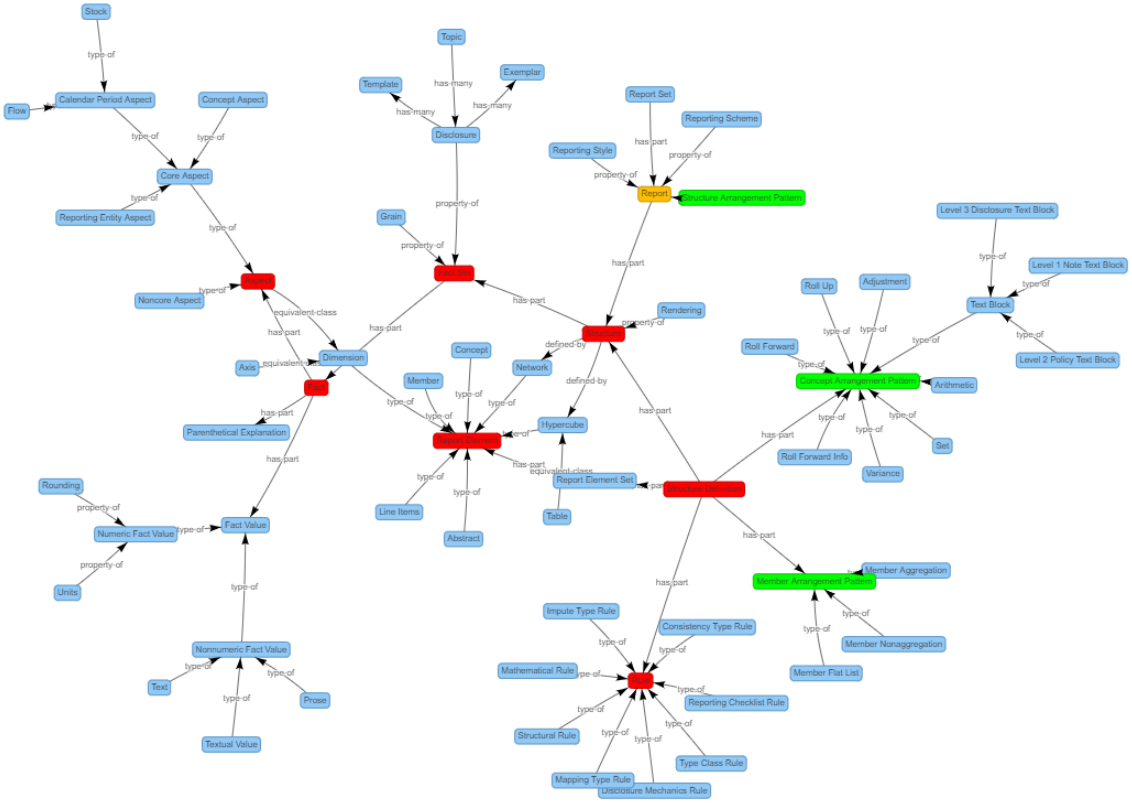
To create a standard financial report logical conceptualization, we want to build on top of a business report logical conceptualization because a financial report is a special type of the more general business report.

6.3. Logical Theory Describing Business Report

The business report metamodel is simply a logical system that is based on a standard logical conceptualization of a business report, the *Standard Business Report Model* (SBRM)[334]. A financial report model is a type of business report model.

The following is an overview of the business report metamodel explained in simple terms.

[333] Charles Hoffman, CPA, et al, *Logical Theory Describing Financial Report*, http://accounting.auditchain.finance/framework/LogicalTheoryDescribingFinancialReport.pdf
[334] OMG, *Standard Business Report Model* (SBRM), https://www.omg.org/intro/SBRM.pdf



For a more detailed explanation of the *Standard Business Report Model* (SBRM), please see the *Narrative Explaining the Logical Conceptualization of a Business Report*[335].

6.4. Logical Theory Describing Financial Report

The financial report metamodel is simply a standard business report model that is further constrained to provide additional artifacts exclusive to financial reports and additional constraints and restrictions. Remember, all financial reports fit into one financial report metamodel that is described by the *Logical Theory Describing Financial Report*[336].

Additional artifacts that are added to the SBRM to meet the needs of a a financial report include:

- Topics
- Disclosures
- Fundamental accounting concepts
- Reporting styles
- Specific type-subtype associations

[335] *Narrative Explaining Logical Conceptualization of a Business Report*, http://accounting.auditchain.finance/sbrm/SBRM-Narrative.pdf
[336] Charles Hoffman, CPA, et al, *Logical Theory Describing Financial Report*, http://accounting.auditchain.finance/framework/LogicalTheoryDescribingFinancialReport.pdf

- Specific consistency rules
- Specific derivation rules
- Templates
- Exemplars

Financial report models can be made unique for each financial reporting scheme including US GAAP and IFRS[337]. A complete inventory of the logical objects that might exist in a financial report is provided by the PROOF representation[338].

6.5. Logical Schema

A financial report knowledge graph can be explained by a logical schema[339]. That logical schema is a data model or structure of a specific area of knowledge expressed independently of a particular database implementation or product. The logical schema constrains and restricts the logical model.

6.6. Very Simple Example of Financial Report Model

We will provide a very basic example of a financial report model to strengthen your understanding of financial report models.

A very simple example of a financial report model is the **accounting equation**. Here is a description of the accounting equation financial report model in both human-readable terms and machine-readable terms using XBRL[340]:

Terms: Three simple terms are defined: Assets, Liabilities, Equity. One complex term is defined, Balance Sheet.

Structure: One structure is defined, the Balance Sheet, and identified using the term Balance Sheet.

Associations: The three terms Assets, Liabilities, and Equity are associated in that they are all PART-OF the structure balance sheet.

Rules: A mathematical assertion is made that "Assets = Liabilities + Equity".

Facts: Instances of three facts are established to exercise the model: Assets of $5,000; Liabilities of $1,000; Equity of $4,000.

Model: All of the terms, associations, rules, structures, and facts describe the model. We created only one model, or permissible interpretation, of the financial report model.

(As accountants know, if you reverse the equation using the rules of math to "Equity = Assets - Liabilities" and change the term "Equity" to "Net Assets"; then you get another permissible interpretation or model. But we are not using that permissible version of the accounting equation within this financial report model.)

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337 Financial Reporting Schemes, http://accounting.auditchain.finance/reporting-scheme/index.html
338 PROOF representation, http://accounting.auditchain.finance/reporting-scheme/proof/documentation/Index.html
339 Wikipedia, *Logical Schema*, https://en.wikipedia.org/wiki/Logical_schema
340 Charles Hoffman, *Accounting Equation*, http://xbrlsite.azurewebsites.net/2020/master/ae/

Because this is a very simple example with only a few logical statements it is easy to get your head around this specific financial report model and see that it is consistent, complete, and precise. As expected, you see three facts described by three terms which are related to one structure and the one rule is consistent with expectation:

Balance Sheet [Abstract]	Period [Axis]
	2020-12-31
Balance Sheet [Abstract]	
Assets	5,000
Liabilities	1,000
Equity	4,000

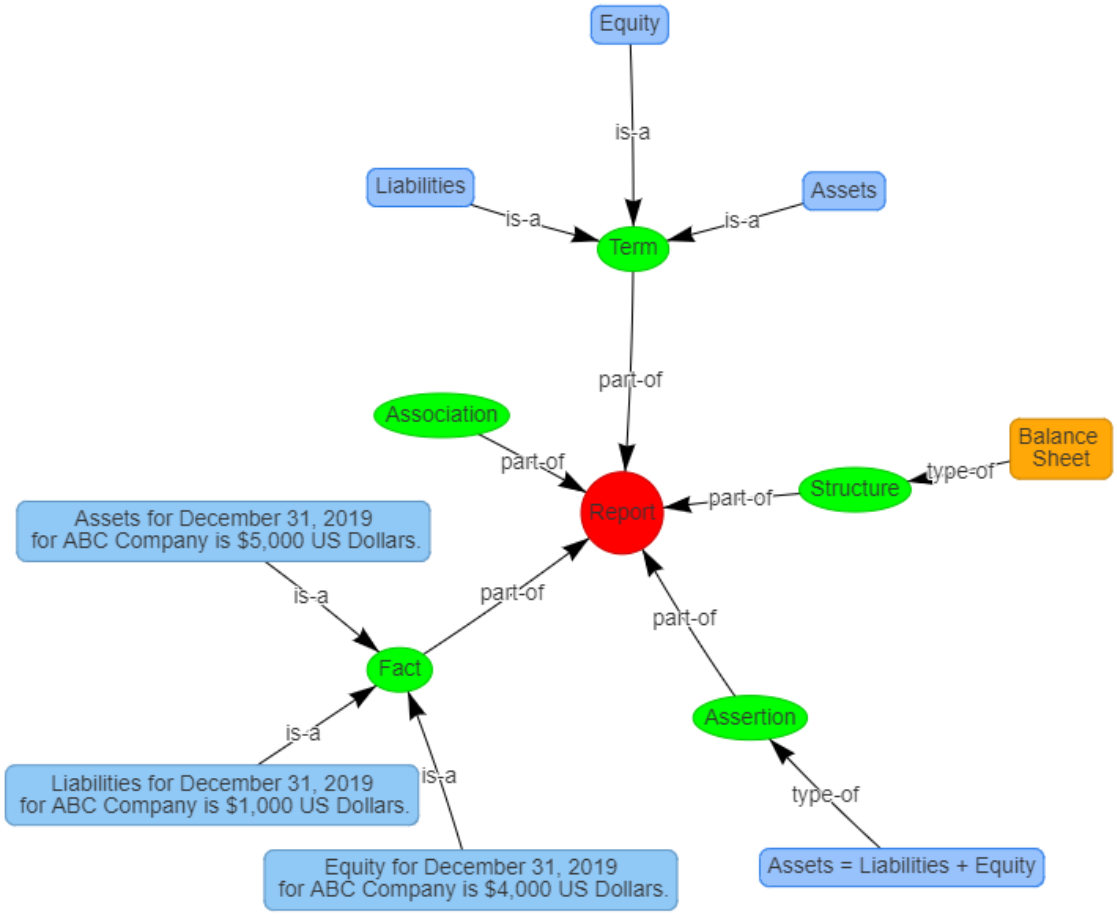
Balance Sheet

Consistent
Complete
Precise
1

Assets = 5,000
Liabilities = 1,000
Equity = 4,000
Assets = Liabilities + Equity

Result	Rule
Pass	$Assets = $Liabilities + $Equity

As the size of the financial report model increases it becomes increasingly more challenging to verify that the logical system is properly functioning using manual processes. We will discuss the types of things that can go wrong with a system in a later section. Essentially, the models, terms, structures, rules, and facts form a labeled directed acyclic graph or knowledge graph such as this simplified knowledge graph which describes the system we are discussing:



Hopefully you get the general idea from this simplified wireframe representation of our logical system as a knowledge graph.

While a typical financial report is significantly larger (i.e. the Microsoft 2017 10-K[341] is made up of 194 structures; 2,035 facts; 3,296 associations; etc.) every financial report works the same as this very simple example but just has more pieces.

6.7. Financial Report Logical Conceptualization in Simple Terms

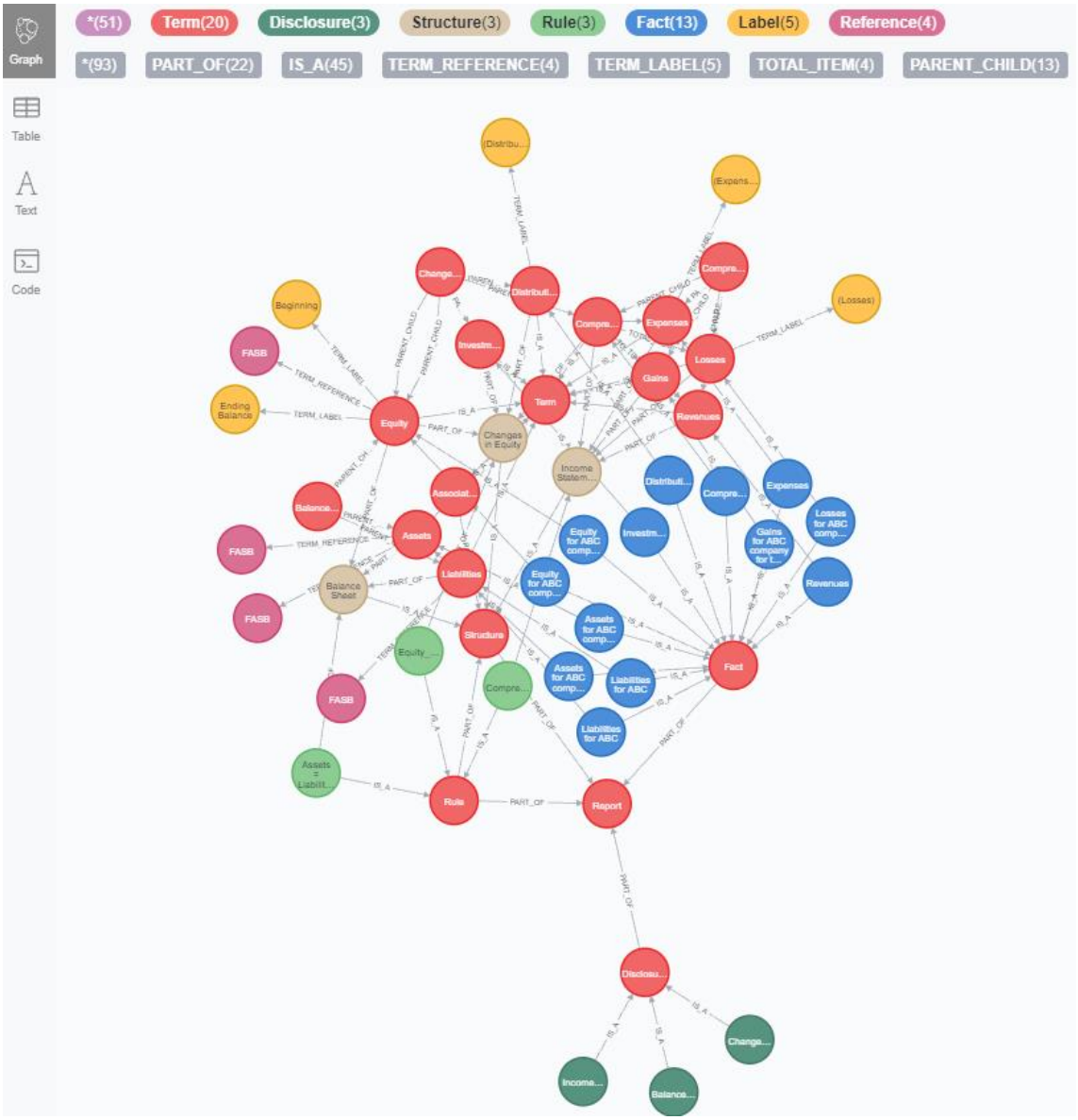
The logical conceptualization of a financial report builds on top of the logical conceptualization of the more general business report. The financial report logical conceptualization takes the general business report logical conceptualization as it's base and adds additional artifacts, constraints, and restrictions related only to financial reporting. For example, financial reports are constrained by the double-entry accounting model, the accounting equation, and other characteristics of financial reporting.

If you want more information about the financial report logical system at this point, I would encourage you two watch the YouTube.com video playlist *Understanding the Financial Report Logical System*[342].

6.8. Visualizing the Financial Report Knowledge Graph

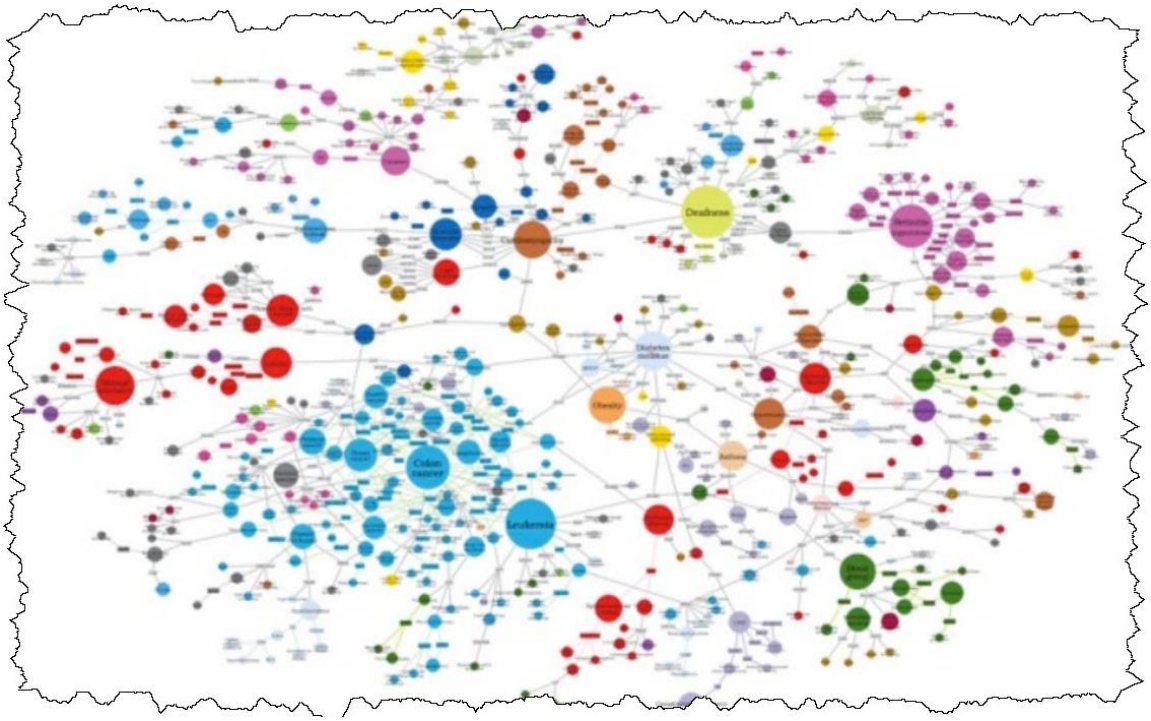
When you work with a financial report knowledge graph in a general-purpose tool for working with any knowledge graph from any area of knowledge, what you see might look something like the following:

[341] Microsoft XBRL-based Report Analysis, http://xbrl.squarespace.com/journal/2020/4/13/microsoft-xbrl-based-report-analysis.html
[342] YouTube.com, Charles Hoffman, CPA, *Understanding the Financial Report Logical System*, https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt

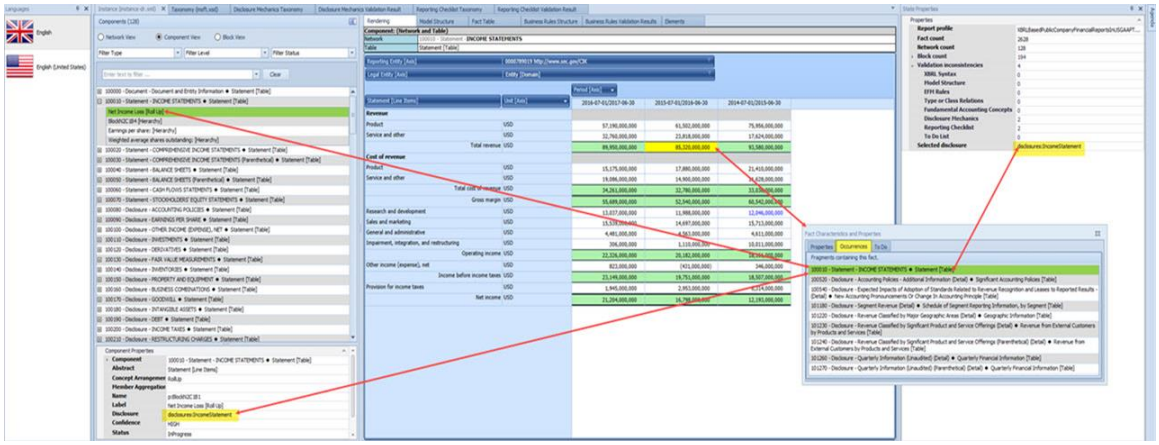


Above you see the knowledge graph of a smaller prototype financial report as seen within Neo4j which is a graph database.

A more comprehensive financial report might look as follows:

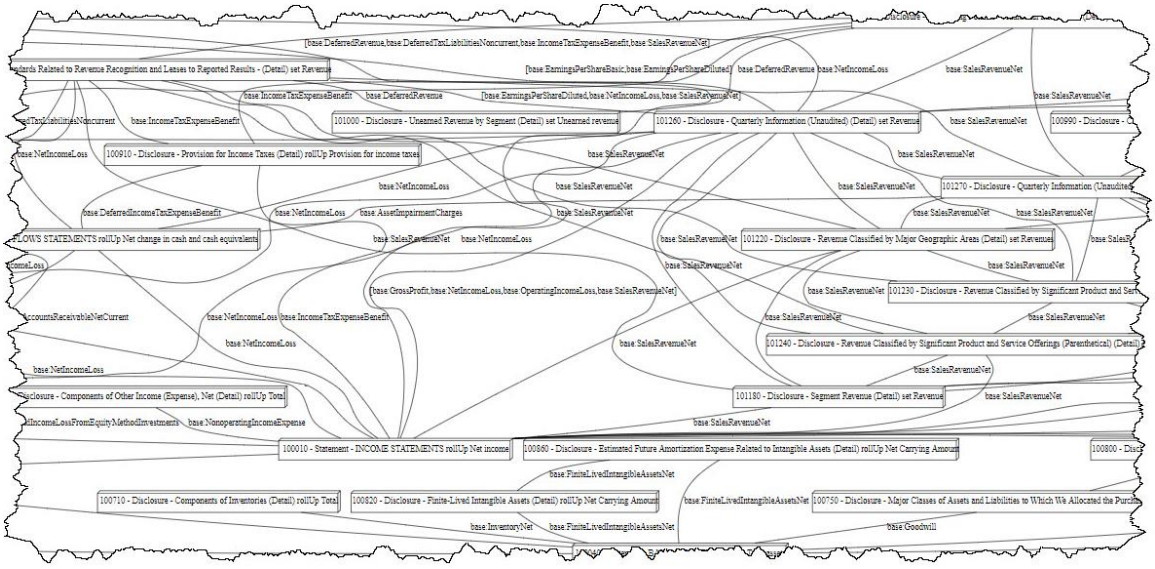


If you look at the same knowledge graph of information about a financial report in a special-purpose tool for working with such financial report knowledge graphs, it might look something like this[343]:



A specialized tool such as Pacioli[344] understands all those edges and vertices within the knowledge graph and the labeled directed acyclic graphs that are represented and can use this information to dynamically work with the financial report logical model. Here is an example of how Pacioli sees a financial report knowledge graph[345]:

[343] *Pesseract*, http://xbrlsite.azurewebsites.net/2021/library/KnowledgeGraph_Pesseract.jpg
[344] *Pacioli Power User Tool*, http://xbrl.squarespace.com/journal/2021/6/29/pacioli-power-user-tool.html
[345] Pacioli report from a financial report knowledge graph, http://accounting.auditchain.finance/demonstrations/msft/blocksGraph.html



If you have the right tools, you can view a comprehensive knowledge graph of the Microsoft 10-K for 2017[346] for which a significant amount of information has been represented for the financial report knowledge graph.

This raises an important point that every financial report knowledge graph must be represented in some physical form, some technical format.

This knowledge graph was represented using the global standard XBRL technical syntax. That standard XBRL technical syntax was simply converted to the PROLOG format which is how Pacioli is implemented and processes the financial report knowledge graph.

6.9. XBRL-based Digital Financial Reports

XBRL is a global standard technical syntax that is used in over 60 countries for representing financial reports. Teaching you to use XBRL is not in the scope of this resource because good software applications will completely abstract the XBRL technical syntax away from professional accountants.

But, if you do want to understand more details about XBRL, there are four helpful resources which you might find helpful:

- *Very Basic XBRL Technical Primmer*[347]: Provides basic information that helps you get started with the XBRL technical syntax.
- *Essentials of XBRL-based Digital Financial Reporting*[348]: Provides essential ideas that you should keep in mind as you are working with XBRL-based digital financial reports.

[346] *Knowledge Graph of Microsoft 10-K Financial Report*, http://xbrl.squarespace.com/journal/2021/7/12/knowledge-graph-of-microsoft-10-k-financial-report.html
[347] Charles Hoffman, CPA, *Very Basic XBRL Technical Primer*, http://www.xbrlsite.com/mastering/Part00_Chapter01.B_XBRLPrimer.pdf

- *The XBRL Book: Simple, Precise, Technical*[349]: Comprehensive technically oriented guide to XBRL.
- *XBRL Specification*[350]: The definitive guide to the XBRL technical syntax specification.

As you can see, the XBRL technical format was supplemented by other logical artifacts to enhance functionality. To enhance the reliability, trust, and provenance of information reported using the XBRL format we leverage digital distributed ledgers provided by a blockchain.

6.10. Levels of Financial Report

To clearly and precisely understand XBRL-based digital financial reporting, it helps to think of the spectrum of financial reports in terms of levels similar to how levels are helpful in understanding the capabilities of self-driving cars[351].

The term "self-driving" means different things to different people so it makes it difficult to have a precise conversation about that topic. But breaking the description into a spectrum of descriptions is very helpful to the communication process.

This is similarly true for the levels of an XBRL-based digital financial report. Below we will break down a financial report into helpful levels[352] that will enable a precise and clear discussion. We will provide a very brief description, a little bit of information, and a link to specific examples that instantiate a report per each specific level.

The marginal difference between each level is very helpful in providing the reader with a solid understanding of the different levels.

Here is an overview of the levels related to financial reporting as I see them beginning with the least functional in terms of both human and machine use of the information from with a financial report.

- **Level 0**: Not machine readable. *An example of Level 0 is a clay tablet, papyrus, or paper as the report medium*.
- **Level 1**[353]: Machine readable, nonstandard, structured for presentation. *PDF, HTML, or XHTML are examples of Level 1*.
- **Level 2**[354]: Machine readable, nonstandard, structured for meaning, no taxonomy (a.k.a. dictionary), no rules, no report model. *An XBRL-based*

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[348] Charles Hoffman, CPA, Essentials of XBRL-based Digital Financial Reporting, http://xbrlsite.azurewebsites.net/2021/essentials/EssentialsOfXBRLBasedDigitalFinancialReporting.pdf

[349] Ghislain Fourny, *The XBRL Book: Simple, Precise, Technical*, https://www.amazon.com/XBRL-Book-Simple-precise-technical/dp/B08RQZJ6VK

[350] XBRL International, *XBRL 2.1 Specification*, https://specifications.xbrl.org/work-product-index-group-base-spec-base-spec.html

[351] Truecar, The 5 Levels of Autonomous Vehicles, https://www.truecar.com/blog/5-levels-autonomous-vehicles/

[352] Financial Report Levels, http://xbrl.squarespace.com/journal/2021/4/5/financial-report-levels.html

[353] Level 1 financial report example, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-level1/

report without an XBRL taxonomy schema, without XBRL relations and resources, and without XBRL Formulas is an example of Level 2.

- **Level 3**[355]: Machine readable, global standard syntax, structured for meaning, with taxonomy (a.k.a. dictionary), incomplete rules, incomplete high-level report model. *An XBRL-based report with a XBRL taxonomy schema, with XBRL relations and resources, but without XBRL Formulas is an example of Level 3.*
- **Level 4**[356]: Machine readable, global standard syntax, structured for meaning, with taxonomy (a.k.a. dictionary), complete set of rules provided, incomplete high-level report model. *An XBRL-based report with a XBRL taxonomy schema, with XBRL relations and resources, and with XBRL Formulas that completely describes the report is an example of Level 4*.
- **Level 5**[357]: Machine readable, global standard syntax, structured for meaning, with taxonomy (a.k.a. dictionary), complete set of rules provided, complete global standard high-level report model, yields PROVEN properly functioning system and UNDERSTANDABLE report information. *An XBRL-based report with all the characteristics of Level 4, plus consistency cross checks, type-subtype relations, consistent modeling of XBRL presentation relations, information that describes the correct representation of every disclosure within the report, and a reporting checklist that describes all required disclosures is an example of Level 5*.
- **Level 6**: All of Level 5 PLUS blockchain-anchored XBRL to increase trust. *An XBRL-based report with all the characteristics of Level 5, plus information within a digital distributed ledger that assures no one has tampered with the report is an example of Level 6*.
- **Level 7**: All of Level 6 PLUS blockchain-anchored accounting transactions and events. *An XBRL-based report with all the characteristics of Level 6, plus information that indicates that assures no one has tampered with transactions is an example of Level 7*.

There is something very important to note here. The set of logical statements that is used to specify/describe how a report should be created (say by a regulator or standards setter), used to actually create a report (say an accountant), verify that the report was created consistently to the specification/description (say an accountant or software application used by an accountant), independently confirm that the report was created consistently with the specification/description (say by an independent auditor), or extract information from the created report (say by a financial analyst or regulator) are all the same set of logical statements.

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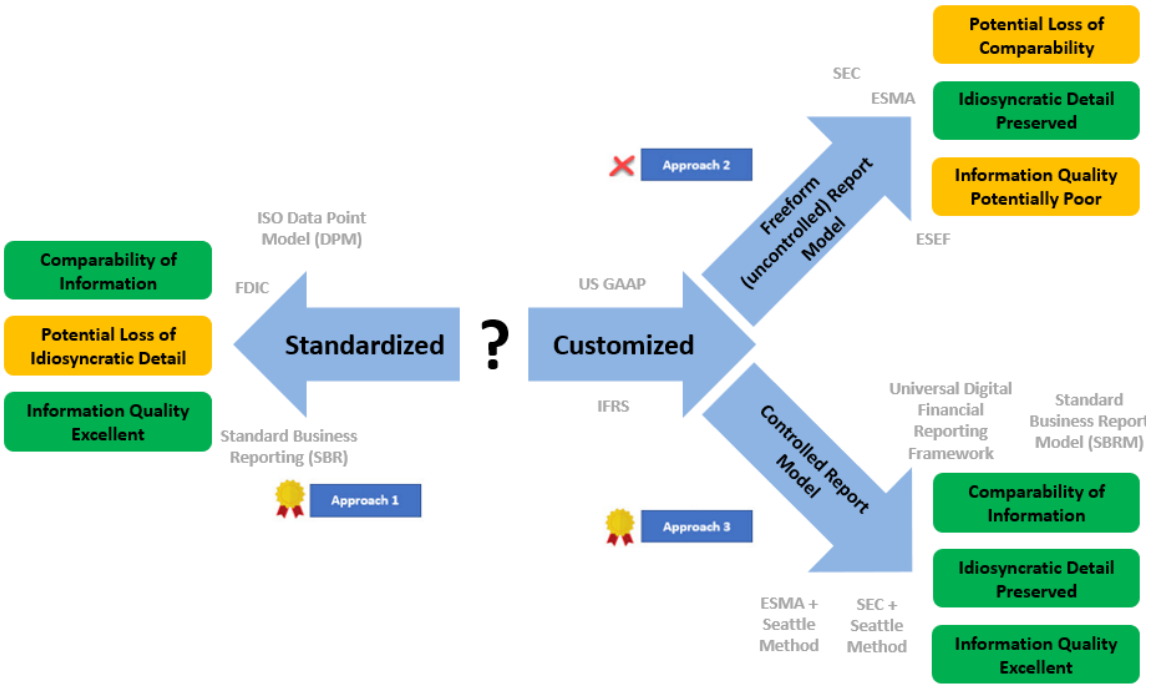
[354] Level 2 financial report example, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-level2/
[355] Level 3 financial report example, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-level3/
[356] Level 4 financial report example, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-level4/
[357] Level 5 financial report example, http://xbrlsite.azurewebsites.net/2021/reporting-scheme/proof/reference-level5/

6.11. Reporting Approaches

The paper *Critical Reflection on XBRL: A "Customisable Standard" for Financial Reporting?*[358], breaks reporting into two approaches: standardized reporting and customized reporting. I modified this breakdown slightly breaking customized reporting into two distinct approaches, "freeform customization" and "controlled customization". I then reflected the three approaches in the following graphic inspired by the graphic in the referenced paper[359]:



This yields three distinct modeling approaches:

- **Standard form model**: No modifications are allowed to the report model.
- **Freeform, Uncontrolled model**: Modifications are permitted to report model, but those modifications are not controlled in any way. As such there is no differentiation between permitted and unpermitted modifications to the model.
- **Controlled model**: Modifications are permitted to report model and a mechanism is provided to control report model modifications; permitted and unpermitted report model modifications are clearly delineated and control mechanisms keep report model modification within permitted boundaries.

Effectively, uncontrolled customization of report models simply will not work.

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[358] Reporting Approaches + XBRL Approaches + Implementation Approaches, http://xbrl.squarespace.com/journal/2021/12/30/reporting-approaches-xbrl-approaches-implementation-approach.html

[359] Taxonomy creation approaches, http://xbrlsite.azurewebsites.net/2022/library/TaxonomyApproachesSeattleMethod.jpg

6.12. Best Practices

A **best practice** (a.k.a. good practices) based method that I am calling the *Seattle Method*[360] was created in order to effectively create XBRL-based financial reports that are provably properly functioning logical systems.

Using this method, enterprises can reliably and effectively stream a high-quality machine-readable XBRL-based global standard knowledge graph of a complete, consistent, and provably correct general purpose financial statement. Further, an entire record-to-report process can be automated effectively. This method provides both the flexibility and the control necessary to effectively hit this target within an enterprise.

The target of this method is Level 5 and above. Below Level 5 the functionality what we generally need from such reports in terms of quality and effective use of reported information in automated machine-based processes is not good enough. It is possible to create a Level 4 XBRL-based report that is properly functioning. Level 5 provides a guarantee that the Level 4 financial report is properly functioning within a provides specification articulated with a complete set of rules. Level 5 measures quality whereas Level 4 quality is essentially based on what amounts to luck or hope which are not effective engineering techniques.

6.13. Modern Accounting

As explained in *Computational Professional Services*[361], unprecedented human-machine collaboration will be made possible using knowledge graphs.

Humans are very capable of carrying out financial accounting, reporting, auditing, and analysis steps and performing tasks. Leveraging knowledge graphs, mechanical devices can also be created to carry out such steps and perform tasks. For example, a vending machine is such a device. A calculator is also such a device. Computers via the software programs they run can likewise carry out steps and perform tasks. Machines will augment humans enabling humans to do what they do best and machines to assist in the steps and tasks that they do best. Entire record-to-report processes can be controlled and therefore automated[362].

Algorithmic Business Thinking[363] will help professional accountants think about the steps and tasks they perform in new ways.

Accounting processes will be modernized for the information age[364].

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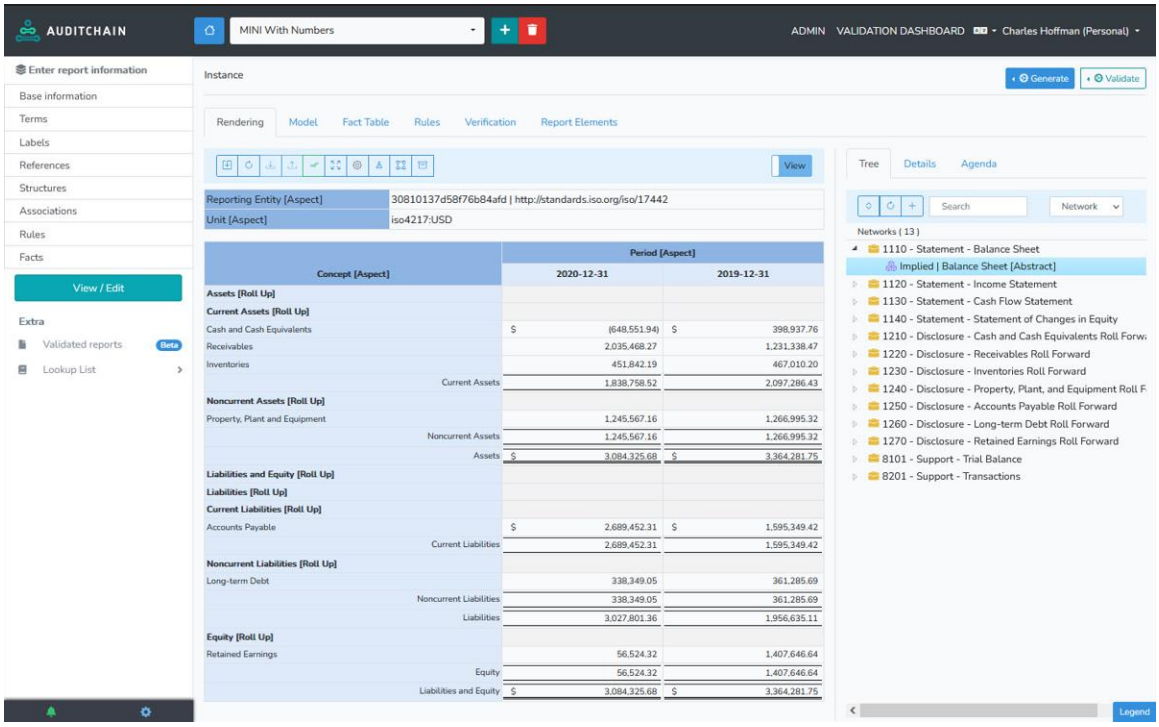
[360] Charles Hoffman, CPA, Seattle Method, http://xbrlsite.com/seattlemethod/SeattleMethod.pdf
[361] Charles Hoffman, CPA, Computational Professional Services, http://accounting.auditchain.finance/library/ComputationalProfessionalServices.pdf
[362] *Effective Automation of Record to Report Process (Iteration #4)*, http://xbrl.squarespace.com/journal/2021/1/25/effective-automation-of-record-to-report-process-iteration-4.html
[363] *Algorithmic Business Thinking*, http://xbrl.squarespace.com/journal/2021/9/22/algorithmic-business-thinking.html
[364] *Modernizing Accounting for Dummies*, http://xbrl.squarespace.com/journal/2021/9/22/modernizing-accounting-for-dummies.html

6.14. Expert System for Creating Financial Reports

One of the uses of a financial report knowledge graph is to create an expert system for constructing financial reports[365]. A logic/rules/reasoning/knowledge/insights engine[366] is used to enforce the logical schema[367] of the financial report knowledge graph.

The closest thing to an expert system for creating a financial report that exists as of this writing is Auditchain Luca[368]. But this is only the beginning.



[365] *Expert System for Creating Financial Reports Explained in Simple Terms*, http://xbrlsite.azurewebsites.net/2022/Library/ExpertSystemForCreatingFinancialReports.pdf
[366] *Pacioli: an XBRL Knowledge Engine*, http://xbrl.squarespace.com/journal/2022/2/19/pacioli-an-xbrl-knowledge-engine.html
[367] *Logical Schema of Financial Reports*, http://xbrlsite.com/seattlemethod/LogicalSchemaOfFinancialReports.pdf
[368] Getting Started with Auditchain Luca, https://digitalfinancialreporting.blogspot.com/2024/01/getting-started-with-auditchain-luca.html

7. Logical System

To understand the new paradigm, you have to change what you see when you think of a financial report and all the accounting working papers and audit schedules that support that report. A financial report is not a piece of paper. A financial report just looks like paper because that is the medium used to exchange the information that is represented on that financial report. Accountants just sprayed information onto that paper because that is the only tool they had. Before the paper accountants chiseled information onto clay tablets. Think not about the exchange medium; think about the information that is being exchanged. Not data; information.

This can be a hard transition, but others have flipped their thinking and so can you. Start by thinking about a financial report as a man-made logical system designed by humans.

7.1. Systems Thinking

Systems thinking[369] is the discipline of seeing wholes. Systems thinking is a framework for seeing logical interrelationships and logical patterns. Systems thinking is based on systems theory and is implemented using systems engineering. Another term for systems thinking is holistic thinking.

7.2. System

A system (a.k.a. formal system) is a cohesive conglomeration of interrelated and interdependent parts that is either natural or designed (man-made). A logical system is a type of system. Systems are organized and have patterns. A system has a describable patterns of logical behavior. The notion of a system is explained by systems theory[370].

The solar system is a type of natural system. A general-purpose financial report is a designed system created by man to serve a very specific purpose.

Logical Systems for Business Professionals[371] helps accountants, auditors, and analysts think about financial report knowledge graphs and the general-purpose financial report logical system.

7.3. Logic

Logic[372] is a formal system/framework that defines the principles and rules of correct reasoning. Logical reasoning is about arriving at a conclusion in a rigorous way. There two broad categories of logical reasoning: deductive and non-deductive.

Deductive reasoning provides a result that is guaranteed to be certain, therefore the result can be relied upon without doubt and humans need not be involved in a process because of the certainty of deductive reasoning. Non-deductive reasoning, on the other hand, is not certain, meaning it could be correct but it could also be

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[369] *Systems Thinking*, https://digitalfinancialreporting.blogspot.com/2023/09/systems-thinking.html
[370] *A Theory of a System for Educators and Managers*, https://youtu.be/2MJ3lGJ4OFo
[371] *Logical Systems for Business Professionals*, https://digitalfinancialreporting.blogspot.com/2023/09/logical-systems-for-business.html
[372] Wikipedia, *Logic*, https://en.wikipedia.org/wiki/Logic

incorrect. Non-deductive reasoning is based on probability. And so non-deductive reasoning approaches must have a human in the loop to deal with that uncertainty. There are three types of non-deductive reasoning: inductive, abductive, and analogy.

Computational logic is a branch of logic and computer science that relates to getting computers to perform correct reasoning. Logic programming languages express facts using machine-readable logical statements, then use software to make sure all the facts are consistent and then draw inferences from these facts. To perform proper logical reasoning, one needs a complete set of logical statements.

That set of logical statements, preferably a complete set of logical statements, is a theory. Theories should be "precise" meaning that they describe an area of knowledge correctly, "consistent" meaning that there are no logical inconsistencies in the theory, and "complete" meaning that they fully represent the area of knowledge given the goals and objectives of the theory.

The tools of logic which provide the foundation for mathematics are leveraged by computers to mimic tools previously available only to humans, opening up the possibility of machines literally mimicking an understanding of knowledge. These tools can perform deductive reasoning, inductive reasoning, and abductive reasoning. Deductive, inductive, and abductive reasoning are different tools that bring different capabilities to the table. Hybrid tools which combine the capabilities of the three different types of logic can be created to maximize the utility of each tool within one combined system.

7.4. Elements of Logic

This blog post was inspired by the article, *Elements of Logic*[373]. For more background details, please see this blog post *Elements of Logic for Accountants*[374]. An area of knowledge can describe the important logic of that system using these building blocks.

There tends to be several different sources of explanations of the elements of logic: philosophy, ontology and knowledge engineers, and computer scientists. These explanations tend to be inconsistent, many are incomplete, and most are either too high level to be useful or provide too much details which becomes overwhelming for business professionals and accountants.

This explanation of the elements of logic is tuned specifically for accountants and is intended to help them understand how to think about XBRL-based digital financial reports.

7.4.1. Atomic Design Methodology

Atomic Design Methodology[375] is an approach that can be used to make software applications easier to use. This is done by burying complexity within software rather than exposing that complexity to software users and forcing them to deal with that complexity.

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[373] OpenAI, Elements of Logic, https://chat.openai.com/share/b2d1dc31-4afd-49e1-8fd2-33b0d651890a

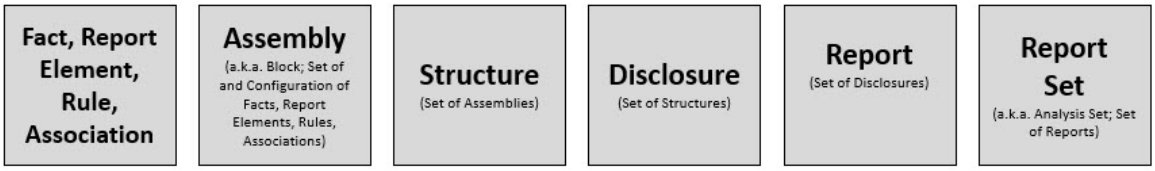
[374] Elements of Logic for Accountants, https://digitalfinancialreporting.blogspot.com/2023/10/elements-of-logic-for-accountants.html

[375] Atomic Design Methodology, https://digitalfinancialreporting.blogspot.com/2023/12/atomic-design-methodology.html

"Atomic design is a methodology composed of five distinct stages working together to create interface design systems in a more deliberate and hierarchical manner."

- **Atoms** are the basic building blocks.
- **Molecules** are combinations of two or more atoms. These combinations of atoms take on their own unique properties, and become more tangible and operational than atoms.
- **Organisms** are assemblies of molecules functioning together as a unit. Organisms are more complex and sophisticated than molecules.

Atomic design methodology provides the high level building blocks that can be used to hide system complexity from system users. Here is an example of the high level building blocks of a financial report:



To better understand the logical objects in XBRL-based financial reports, please see *Understanding Logical Objects of XBRL-based Digital Financial Reports*[376].

7.4.2.Logical System Explained in More Detail

The **elements of logic** are the fundamental **building blocks** of logical theories that describe the logical conceptualization of some natural or man-made logical system.

- **Logical statement**: A logical statement is a proposition, claim, assertion, belief, idea, or fact about or related to the area of knowledge to which the logical conceptualization relates. A logical statement is a declarative sentence. Not all sentences are statements; for example, a question such as "What is your name?", or a command such as "Stop!", are not statements. There are five broad categories of logical statements:
  - **Terms**: Terms are important logical statements that define ideas or "things" used by a logical conceptualization. For example, "assets", "liabilities", "equity", and "balance sheet" are things or ideas used in a logical conceptualization.
  - **Associations**: Associations are important logical statements that describe permissible interrelationships between the terms such as "assets is part-of the balance sheet" or "operating expenses is a type-of expense" or "assets = liabilities + equity" or "an asset is a 'debit' and is 'as of' a specific point in time and is always a monetary numeric value". Associations can be grouped into two broad groups:
    - "**Is-a**" (a.k.a. general-special, association, type-subtype, class-subclass, equivalent-class)
    - "**Has-a**" (a.k.a. part-of, has-part, part-whole, composition, aggregation)

[376] *Understanding Logical Objects of XBRL-based Digital Financial Reports*, http://xbrlsite.com/2024/Library/UnderstandingLogicalObjects.pdf

- **Rules**: Rules (a.k.a. assertions, restrictions, constraints) are important logical statements that describe what tend to be convertible into IF…THEN…ELSE types of relationships such as "IF the economic entity is a not-for-profit THEN net assets = assets - liabilities; ELSE assets = liabilities + equity". One rule can be connected to another rule using logic gates[377] (AND, OR, NOR, NAND, XOR, XNOR, NOT) to form complex logical statements. Rules can assert mathematical relationships or derive mathematical relationships to form new facts.
- **Facts**: Facts are important logical statements that are known to be true. In the context of databases and knowledge representation, facts are often used to represent known information. Facts are logical statements about the numbers and words that are provided by an economic entity within a financial report. For example, the financial report might state "assets for the consolidated legal entity Microsoft as of June 20, 2017 was $241,086,000,000 expressed in US dollars and rounded to the nearest millions of dollars.
- **Properties:** Properties are important logical statements about the important qualities and traits of a model, structure, term, association, rule, and fact.

- **Axioms:** Axioms are foundational logical statements that are fundamentally accepted as being true per some logical system.
- **Theorems**: Theorems are logical statements that are determined to be true per logical steps that can be taken to arrive at a conclusion using axioms, other theorems, of facts.
- **Assertion**: Something that you hold to be true.
- **Restriction**: Restrictions are a special type of axiom or theorem that is imposed by some authority which chooses to restrict, constrain, limit, or otherwise impose some range on some logical artifact.
- **Classification**: Classification is the grouping of logical artifacts into sets.
- **State or state of affairs**: The current state of a system.
- **Situation**: An event, circumstance, or phenomenon that impacts state or changes to current state of affairs.
- **Infon**: A unit of information.
- **Logical structure**: A logical structure is as set of logical statements which describe the structure. An "infon" which is defined by Situation Theory is a unit of information[378]. In infon is a type of logical structure. An infon is a useful, convenient unit or "set" of information.
- **Logical model**: A logical model is a set of specific structures that are consistent with and permissible interpretations of that model. Models add flexibility to logical conceptualizations.

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[377] *Logic Gates: The Building Blocks of Digital Circuits*, https://www.linkedin.com/pulse/logic-gates-building-blocks-digital-circuits-deekshith-kumar/

[378] *Describing Situation Semantics Using Situation Theory*, https://digitalfinancialreporting.blogspot.com/2023/10/describing-situation-semantics-using.html

- **Logical conceptualization**: A logical conceptualization is a set of models that are consistent with and permissible per that logical conceptualization. A logical conceptualization is made up of a set of models, structures, terms, associations, rules, and facts.
- **Logical theory**: A logical theory is described per some logical conceptualization forms a logical theory that explains what is permitted and what is not permitted per a logical conceptualization which is made up of a set of logical models, structures, terms, associations, rules, and facts.
- **Logical system**: A logical system can be explained by a logical theory. A logical theory is an abstract conceptualization of specific important details of some area of knowledge. The logical theory provides a way of thinking about an area of knowledge by means of deductive reasoning to derive logical consequences of the logical theory.

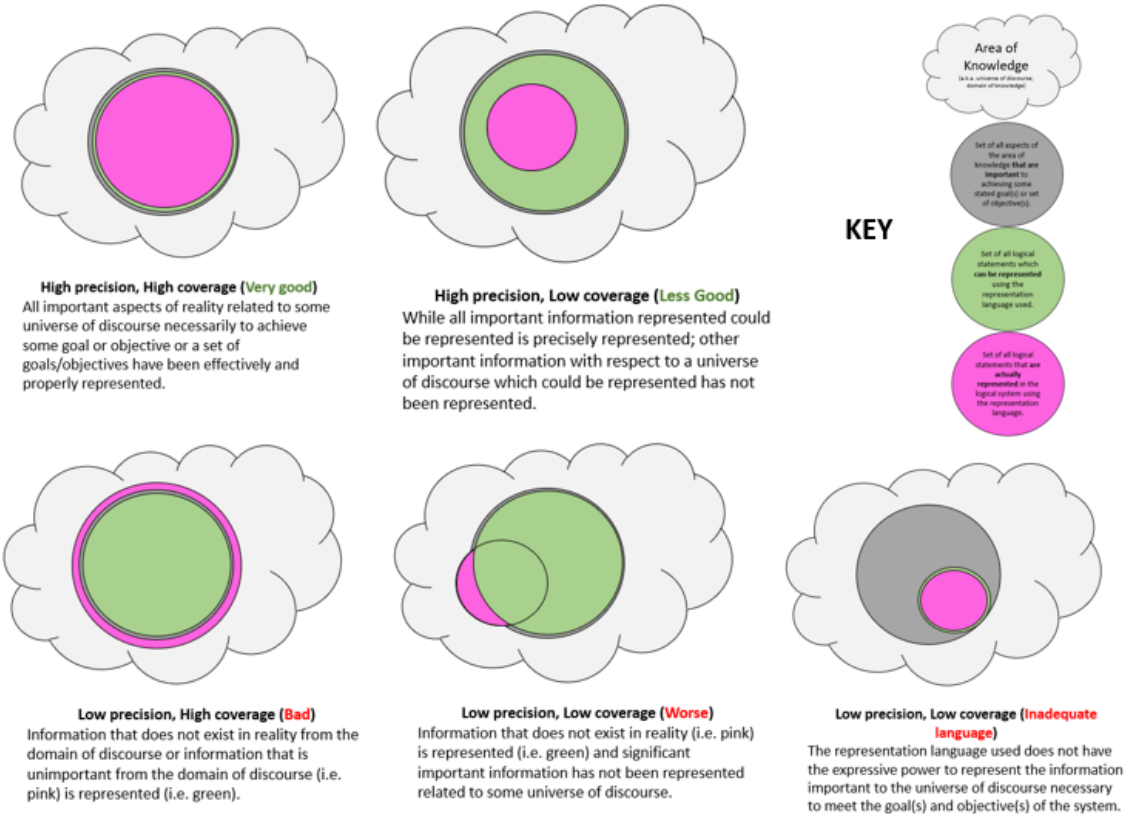
A logical system described by a logical theory and described by a logical conceptualization enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives for an area of knowledge to agree on important logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

A logical conceptualization must be **consistent** (as opposed to inconsistent, making contradictory statements), **complete** (as opposed to incomplete, leaving a piece out), and **precise** (as opposed to imprecise, describing an area of knowledge incorrectly).

7.4.3.Precision, Coverage, Consistency

Quality matters in financial reporting. When representing information in the form of a logical digital twin, things can go wrong and one needs to be couscous about understand what can go wrong and mitigating those situations. The graphic below is inspired by C. Maria Keet, *An Introduction to Ontology Engineering*[379]:

[379] C. Maria Keet, An Introduction to Ontology Engineering, pages 8-9, https://people.cs.uct.ac.za/~mkeet/files/OEbook.pdf#page=23



7.4.4.Control

Because the creators of financial reports are permitted to modify a report model; the system needs to be able to control those modifications to make sure the modifications stay within permitted boundaries. The documents *Financial Report Knowledge Graphs* and *Essence of Accounting*[380] help you understand the dynamics of a financial report.

US GAAP and IFRS based financial reports are not forms. The *Seattle Method*[381] is an approach to managing flexibility. The *Seattle Method* is a proven, industrial strength, good practices, standards-based pragmatic approach to creating provably high quality XBRL-based general purpose digital financial reports when reporting entities are permitted to modify the report model.

The focus of the *Seattle Method* is financial reporting using financial reporting schemes such as US GAAP, IFRS, UK GAAP, and other schemes where the preparer of a financial report is permitted to modify the report model. Because modification of the report model is allowed, those modifications must be controlled to keep the modifications within permitted boundaries.

Without control, there can be no automation, no repeatable processes. Rules provide control. Control leads to high quality. High quality leads to effective automation. Accountants manage the rules.

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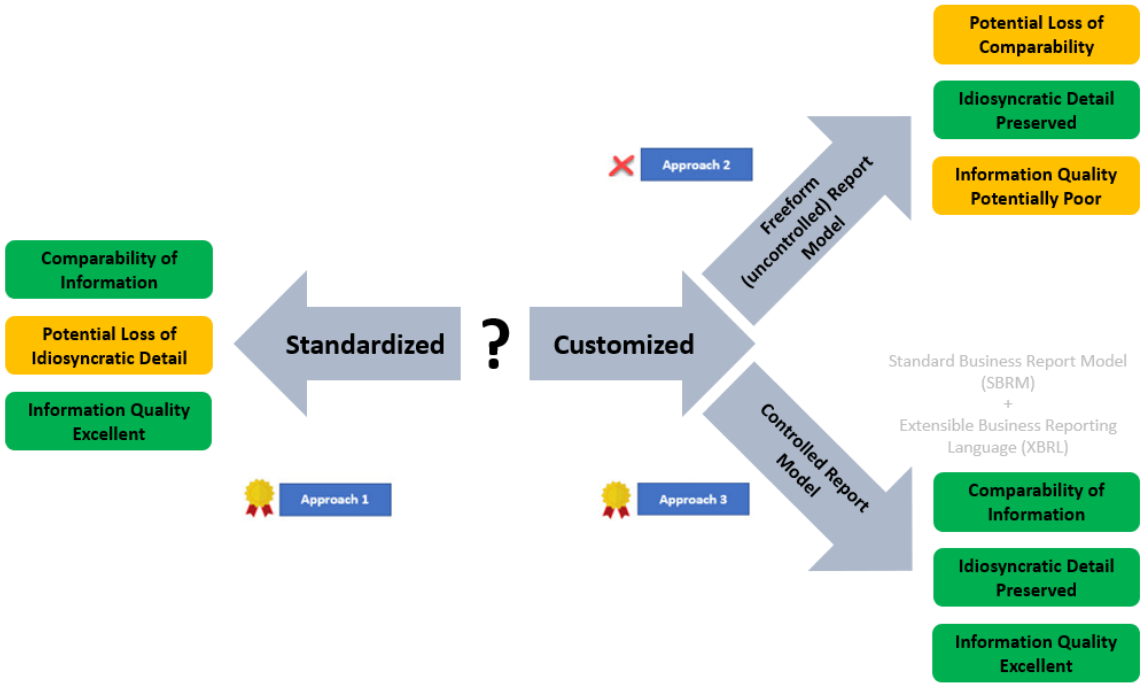
[380] Essence of Accounting, https://xbrlsite.azurewebsites.net/2020/Library/EssenceOfAccounting.pdf
[381] *Seattle Method*, http://xbrlsite.com/seattlemethod/SeattleMethod.pdf



Because financial reports are customized systems; those customizations need to be controlled. The Seattle Method and SBRM help enable that control.

Machine readable rules are used to control systems. In addition, the rules describe the system and are available for software applications to use in order to provide functionality to using software to interact with machine readable financial reports. Rules do the following:

- Elimination of "**wild behavior**" by accountants when report model can be modified
- **Description** of report (specification of what is permitted); created by standards setter or regulator or anyone else specifying a report
    - Machine ***readable form***
    - Machine readable form converted to ***human readable form***
- **Create** report based on description (assisted by software utilizing machine readable description)
- **Verify** that report has been created per description (assisted by software utilizing machine readable description)
- **Extract** information from report per report description (assisted by software utilizing machine readable description)

A financial statement tells a story. That financial report is an information product which sends a signal. Those creating reports want to make sure that the signal communicated is the signal that they intended to be communicated.

7.4.5.Flexibility

Flexibility in-and-of-itself is not a good or bad thing. Flexibility in the right areas is a feature. Undesirable flexibility is a bug. The trick is to provide flexibility in the precise areas that the flexibility is needed and to control that flexibility to guide logical system users where you desire them to go.

To achieve the desired level of flexibility in exactly the correct areas it is critically important to understand the moving puzzle pieces of the logical system. To do that, you need to correctly understand the goal(s) and objective(s) of all of the stakeholders of the logical system.

7.4.6.Classification

It was the Greek philosopher Aristotle (384-322 B.C.) that first came up with the idea of classifying plants and animals by type[382], essentially creating the notion of a hierarchy or taxonomy. The idea was to group types of plants and animals according to their similarities thus forming something that looked like a "tree" with which most people are familiar.

People tend to be less familiar with the notion of a "graph[383]". A tree, or hierarchy, is actually a type of graph. Trees/hierarchies tend to be easier to get your head around. But the real world can be more complicated than the rather simple relations that can be represented by trees/hierarchies. So, graphs[384] are used.

Classification provides three things. First, you can **describe** the model of something. Second, you can use that description of the model to **verify** an instance of the model of something against that provided description. To the extent that you have machine-readable rules, that verification process can be automated. Third, you **explain** or spell out or tell a software application (software algorithm, AI) knowledge about the *state* of where you are in your *agenda* of *tasks* necessary to meet some *goal*. To the extent that you have machine-readable rules, software can assist human users of the software in completing the *tasks* in their *agenda* and achieving that *goal*.

In his book, *Everything is Miscellaneous*[385], David Wenberger points out that every classification system has problems. Every classification scheme ever devised inherently reflects the biases of those that constructed the classification system. The role metadata plays in allowing you to create your own custom classification system so you can have the view of something that you want. The best thing to do about this is to create a flexible enough classification system to let people classify things how they might want to classify them, usually in ways unanticipated by the creators of the classification system.

Wenberger also points out the power of metadata and the three orders of order. First order of order, second order of order, and third order of order.

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[382] Lois Tilton, *From Aristotle to Linnaeus: the History of Taxonomy*, https://davesgarden.com/guides/articles/view/2051
[383] Wikipedia, *Graph Theory*, https://en.wikipedia.org/wiki/Graph_theory
[384] Maël Fabien, *Introduction to Graphs (Part 1)*, https://towardsdatascience.com/introduction-to-graphs-part-1-2de6cda8c5a5
[385] See, http://xbrl.squarespace.com/journal/2011/1/31/us-gaap-taxonomy-build-it-to-allow-reoganization.html

- **First order of order**. Putting books on shelves is an example the first order of order.
- **Second order of order**. Creating a list of books on the shelves you have is an example of second order of order. This can be done on paper or it can be done in a database.
- **Third order of order**. Adding even more information to information is an example of third order of order. Using the book example, classifying books by genre, best sellers, featured books, bargain books, books which one of your friends has read; basically, there are countless ways to organize something.

In fact, the third-order practices that make a company's existing assets more profitable, increase customer loyalty, and seriously reduce costs are the Trojan horse of the information age. As we all get used to them, third-order practices undermine some of our most deeply ingrained ways of thinking about the world and our knowledge of it.

7.5. Knowledge

Knowledge[386] is a form of familiarity with information from some specific area. Knowledge is often understood to be awareness of facts, having learned skills, or having gained experience using the things and the state of affairs (situations) within some area of knowledge. Professional accountants, auditors, and analysts understand all this for their area of knowledge, their industry specialty, for the financial reporting schemes with which they work.

Knowledge of facts is distinct from opinion or guesswork by virtue of justification or proof. Knowledge is objective. Opinions and guesswork are subjective. In our case we are talking about certain specific knowledge, the facts that make up that knowledge, being able to create a proof to show the logic of a knowledge graph system is complete, consistent, and precise; and all of this logic being put into a form readable by a machine and reach a conclusion.

Effectively, a machine can read that logic within a knowledge graph and mimic understanding of that knowledge represented in that logical knowledge graph and the information available to both a human reader and a machine reader would be the same and therefore the human and machine should reach the same conclusion. Regardless of the technical syntax used to represent that logical knowledge graph; the logic of the knowledge representation MUST always be the same no matter what technical format is used to represent the knowledge graph.

Philosophy is a formal discipline which provides tools and techniques for the systematic study of specific things including knowledge and reasoning.

7.6. Area of Knowledge

An **area of knowledge** is a highly organized socially constructed aggregation of shared knowledge for a distinct subject matter. An area of knowledge has a specialized insider vocabulary, underlying assumptions (axioms, theorems, constraints), and persistent open questions that have not necessarily been resolved (i.e. flexibility is necessary).

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386 *All About Knowledge*, https://digitalfinancialreporting.blogspot.com/2023/06/knowledge.html

Accounting is an area of knowledge. You can explain aspects of the accounting area of knowledge, such as the nature of a financial report, using a logical theory which explains a logical model of that financial report. A logical theory can be tested and proven by providing a proof. When all the details are worked out, you have a best practice based proven method.

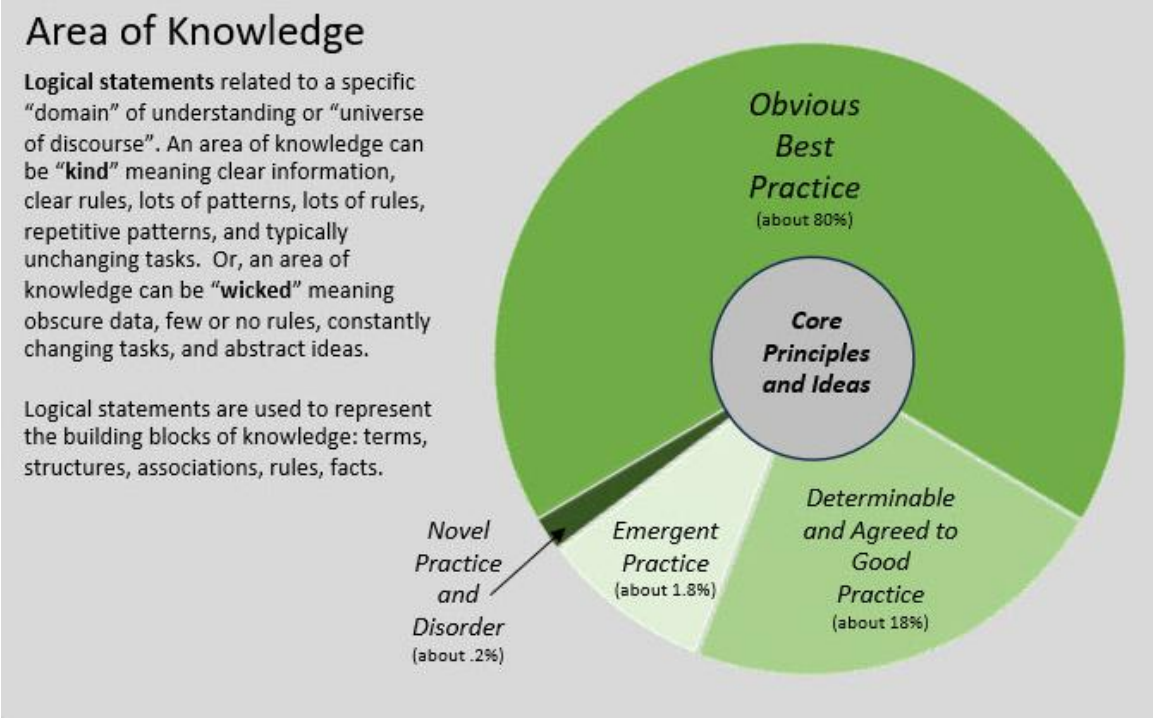
Knowledge can be represented in human-readable form, in machine-readable form, or in a machine-readable form that can be effectively and consistently converted into human-readable form.

You can think about an area of knowledge as being characterized in a spectrum with two extremes:

- **Kind area of knowledge**: clear rules, lots of patterns, lots of rules, repetitive patterns, and unchanging tasks.
- **Wicked area of knowledge**: obscure data, few or no rules, constant change, and abstract ideas.

An area of knowledge can have aspects of both extremes, but tends to lean toward one side of the spectrum or the other. Accounting tends to lean more toward the "kind" end.

Another term for area of knowledge is a knowledge domain, universe of discourse, or simply domain.



Accountants, auditors, and analysts need to make choices about how to organize their area of knowledge and sometimes they confuse what is driving the choice they make or why they have to make that choice. Accountants, auditors, and analysts need to be able to effectively differentiate:

- **Judgement**; not every choice relates to "professional judgement"; picking between permitted alternatives using their skills and experience

- **Ambiguity**; unintended ambiguity exists in accounting standards, just as ambiguity tends to exist in pretty much everything humans create; this is one reason why the tax code grows, and grows, and grows...
- **Skills and experience**; not every accountant has the same level of skill and experience in every practice area of financial accounting or reporting; most accountants are average; not every disclosure created in a financial report is an "art project"; less than 10% tends to be the art, 90% tends to be straight forward, mechanical, rote.

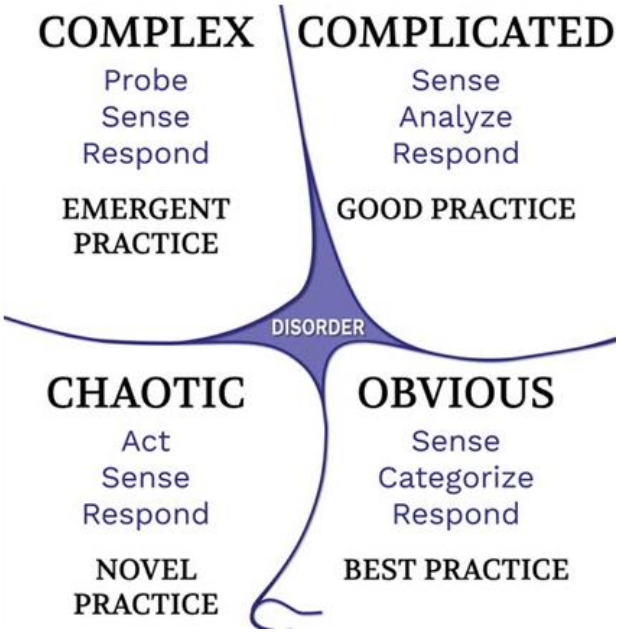
A system is collection of interacting components. An undisputed core of an area of knowledge should serve as a foundation upon which to then build. Only the subject matter experts of an area of knowledge can determine what is important and what is an unimportant trivial detail.

7.7. Complexity and Order

Difference systems have different levels of complexity. Systems can also be ordered or disordered. The *Cynefin Framework*[387] is a conceptual framework that helps you understand the dynamics that are at work within different types of systems. The framework was created in 1999 by David Snowden of IBM Global Services to help IBM to manage intellectual capital.

The following graphic helps one understand the different levels of complexity: simple, complicated, complex, and chaotic. The graphic also helps one understand the difference between disorder and order.

The video *Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements*[388] provides an excellent walk through of these ideas.



[387] Cynefin Framework, http://xbrl.squarespace.com/journal/2021/3/21/cynefin-framework.html
[388] Using Cynefin to Prioritize and Analyze Features, User Stories, and Functional Requirements, https://www.youtube.com/watch?v=L5fnxahydXM

Different skill sets are necessary to be able to create simple, complicated, and complex systems that work effectively.

Sensemaking is the process of determining the deeper meaning or significance or essence of the collective experience for those within an area of knowledge. The Cynefin Framework provides a tool for understanding knowledge. The Cynefin framework categorizes knowledge into the following groupings:

- **Best practices**: things that tend to be obvious even to people outside an area of knowledge. There tends to be only one way to do something which makes sense.
- **Good practices**: things that are a bit more complicated but the subject matter experts within an area of knowledge that have skills and experience tend to agree on these practices. Different groups can use different preferred good practice approaches as a matter of policies.
- **Emergent practices**: things that are even more complex and subject matter experts within an area of knowledge tend to disagree with one another as to what the good practices are which leads to multiple different views, each which is reasonable based on the principles of an area of knowledge and the logical patterns of the situation. There tends to be tight, identifiable clusters of answers. (For example, if accounting standards have ambiguity and accountants apply fundamental principles to figuring out a situation and say each of the Big 4 CPA firms; PWC, Deloitte, EY, KPMG; each come up with a view on how to handle that situation; each view could be correct)
- **Novel practice**: this is similar to emergent practices except that there are no identifiable logical patterns of the situation and no identifiable principles that can be applied; but logical answers can be figured out but the clustering of answers is more spread out, not as tight.

Disorder of an area of knowledge is information not able to be ordered in any meaningful way.

7.8. Symbolic Systems

Stanford University has a unique undergraduate or graduate major offering called the *Symbolic Systems Program*[389].

So, what is a symbolic system? Per the associate director of the program when interviewed by The Stanford Daily[390]:

"[The major is] a combination of studying the human mind … and the intelligence of machines and of the design interaction that happens between them, [as well as] how those things can inform each other," said symbolic systems associate director Todd Davies '84 M.S. '85 Ph.D. '95 in an interview with The Daily."

A symbol is something that represents something else. Symbols can be arranged into structures such as lists, hierarchies, or networks and these structures show how symbols relate to each other.

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[389] Stanford University, *Symbolic Systems Program*, https://symsys.stanford.edu/about/span-dig-deep-solve-complex-problems

[390] Stanford University, *The Stanford Daily*, https://www.stanforddaily.com/2019/01/23/unique-to-stanford-symbolic-systems/

A **symbolic system** is essentially a system built with symbols such as natural language, programming languages, mathematics, or formal logic. Symbolic artificial intelligence[391] uses symbolic systems and rules to restrict systems to operate within permitted boundaries and to reason against the system.

An interesting thing is that symbolic systems are understandable by both humans and by computers.

You can get a more detailed understanding of symbolic systems from the Stanford Bulletin[392] which describes the course. Cognitive science[393] is somewhat similar to symbolic systems. Computational linguistics[394] is also somewhat similar.

Why is this important?

7.9. Rearranging Abstract Symbols

In his book *Saving Capitalism*[395], Robert Reich describes three categories that all modern work/jobs fit into:

- **Routine production services** which entail repetitive tasks,
- **In-person services** where you physically have to be there because human touch was essential to the tasks,
- **Symbolic-analytic services** which include problem solving, problem identification, and strategic thinking that go into the manipulation of symbols (data, words, oral and visual representations).

In describing the third category, symbolic-analytic services, Mr. Reich elaborates:

"In essence this work is to rearrange abstract symbols using a variety of analytic and creative tools - mathematical algorithms, legal arguments, financial gimmicks, scientific principles, powerful words and phrases, visual patterns, psychological insights, and other techniques for solving conceptual puzzles. Such manipulations improve efficiency-accomplishing tasks more accurately and quickly-or they better entertain, amuse, inform, or fascinate the human mind."

Think Computational Law[396] and Computational Audit[397]. Many tasks in accounting, reporting, auditing, and analysis are related to symbolic-analytic services and rearranging abstract symbols. As I pointed out a while back, the "Learn to code" is a hysteria and is misguided. If you want to understand things like how artificial intelligence actually works and how it will impact accounting, reporting, auditing, and analysis; study symbolic systems and logic.

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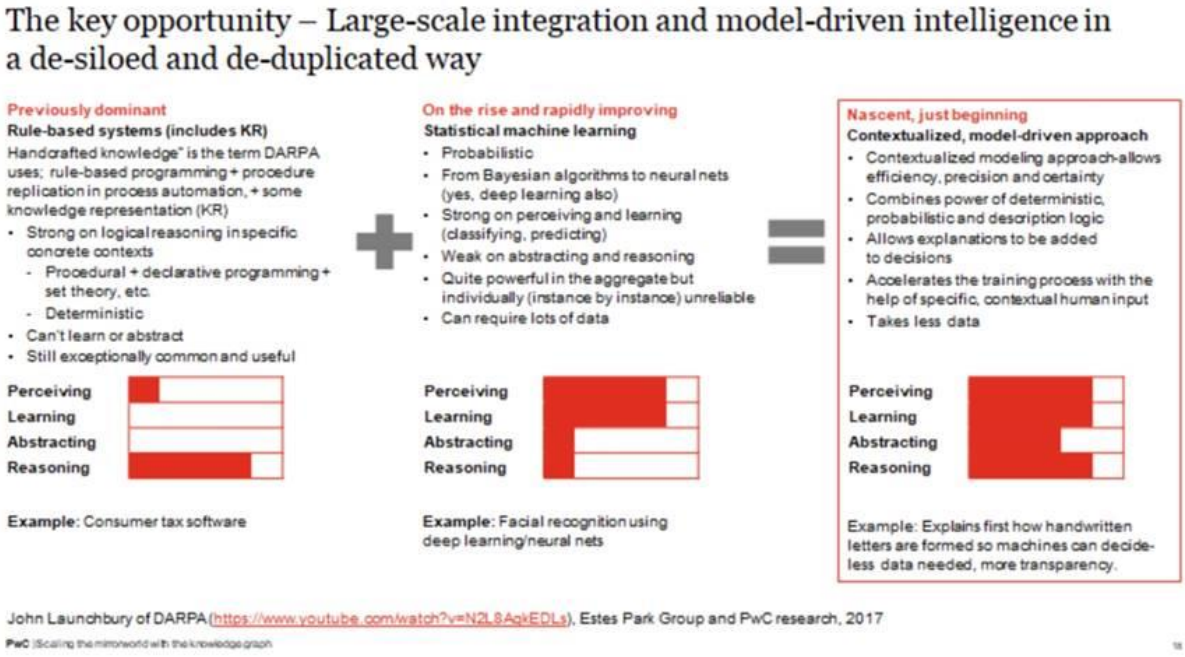
[391] Wikipedia, *Symbolic Artificial Intelligence*, https://en.wikipedia.org/wiki/Symbolic_artificial_intelligence
[392] Stanford University, *Stanford Bulletin*, https://exploredegrees.stanford.edu/schoolofhumanitiesandsciences/symbolicsystems/
[393] Wikipedia, *Cognitive Science*, https://en.wikipedia.org/wiki/Cognitive_science
[394] Wikipedia, *Computational Linguistics*, https://en.wikipedia.org/wiki/Computational_linguistics
[395] Robert Reich, *Saving Capitalism*, page 204-206), https://www.amazon.com/Saving-Capitalism-Many-Not-Few/dp/0345806220
[396] *Computational Law*, http://xbrl.squarespace.com/journal/2020/8/24/computational-law.html
[397] *Computational Audit*, http://xbrl.squarespace.com/journal/2020/8/25/computational-audit.html

A logical system is a type of symbolic system. A logical theory can describe a logical system; for example, the *Logical Theory Describing Financial Report*[398] describes the financial report logical system. Not only is a financial report a type of logical system; that logical system can be readable and understandable by both humans and by machines.

7.10. Programmed Ability to Process Information

Both symbolic systems and non-symbolic systems offer useful capabilities[399]. Be sure to understand the capabilities of these different approaches and use the right tool for the job.

DARPA and PWC do an excellent job of explaining the capabilities of artificial intelligence. This presentation[400], video[401] and this article[402] provide a summary worth reading.



The graphic above shows three approaches to implementing artificial intelligence or the programmed ability to process information. Auditchain's Pacioli is a "rule-based system" that uses "handcrafted knowledge" that I created (the LEFT SIDE). Statistical machine learning will be added (the MIDDLE) to Pacioli over time most likely. Ultimately, where Auditchain and others will end up is on the RIGHT

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398 *Logical Theory Describing Financial Report*, http://www.xbrlsite.com/mastering/Part02_Chapter05.B_LogicalTheoryDescribingFinancialReport.pdf

399 Richa Bhatia, *Understanding the difference between Symbolic AI & Non Symbolic AI*, https://analyticsindiamag.com/understanding-difference-symbolic-ai-non-symbolic-ai/

400 DARPA, *A DARPA Perspective on Artificial Intelligence*, https://www.darpa.mil/attachments/AIFull.pdf

401 YouTube.com, *A DARPA Perspective on Artificial Intelligence*, https://youtu.be/-O01G3tSYpU

402 Quora, Alan Morrison, *What is the relation between Semantic Web and AI?*, https://www.quora.com/What-is-the-relation-between-Semantic-Web-and-AI/answer/Alan-Morrison?ch=2&oid=180785119&srid=Mru&target_type=answer

side which is the combined capabilities of rules-based systems and statistical machine learning. I suspect that this will occur within three to five years.

Here is another explanation that was inspired from a DARPA presentation[403]. Artificial intelligence is defined as a "**programmed ability to process information**". Sure, software like, Excel and Word can process "stuff"; but they don't really understand anything about accounting, reporting, auditing, or analysis.

By "understand", this is what is meant, paraphrasing form the DARPA explanations of these terms:

- **Perceive**: ability to perceive rich, complex, subtle information.
- **Learn**: ability to learn about that information within a specific environment such as within a financial report.
- **Abstract**: ability to create new meaning from existing information.
- **Reason**: ability to plan, ability to decide, ability to verify.

The following graph shows where most software currently is today in terms of helping accountants get their jobs done in terms of accounting knowledge (i.e. basically, you can think of this is the manual tasks and processes that is being performed now)

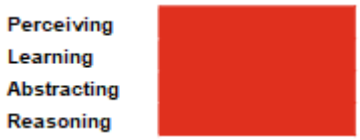
But this is where something like Auditchain's Pacioli is in terms of perceiving, learning, abstracting, reasoning when it comes to the information within a financial report: (Pacioli can do this NOW using my "handcrafted knowledge" a.k.a. standard machine-readable rules represented using XBRL)

The next graphic shows where Pacioli might ultimately go when statistical machine learning is combined with the rules-based system. The rules-based system's handcrafted rules act as a starter set of the rules needed to make the statistical machine learning work. Basically, the rules-based system focuses on what it can do best and the statistical machine learning focuses on what it can do best and the result is a combination of the two approaches: (Auditchain may be here in three to five years in my view)

The final graphic is what full automation looks like. To understand what "full automation" is one would need to understand the specific details of what is being

[403] DARPA, *A DARPA Perspective on Artificial Intelligence*, https://www.darpa.mil/attachments/AIFull.pdf

automated. But also keep in mind that while automation might be possible for some things, for other things it really is not realistic or even necessary to automate to derive value from automation. Making a process 50% more efficient or even 25% more efficient or only 10% more efficient is still quite valuable.



To summarize, there are three very important points to remember here. First, the right artificial intelligence should be used for each automation task. Second, handcrafted metadata is necessary to make automation actually work. Finally, while it is easy to discuss automation in general high-level terms; when you actually automate something you need to work with the details of what is being automated.

7.11. Important to Use the Right Tool for the Job

Machine learning or deep learning systems work best if the system you are using them to model has a high tolerance to error. These types of systems work best for:

- capturing associations or discovering regularities within a set of patterns;
- where the volume, number of variables or diversity of the data is very great;
- relationships between variables are vaguely understood; or,
- relationships are difficult to describe adequately with conventional approaches.

Machine learning basically uses probability and statistics, correlations[404]. This is not to say that machine learning is a bad thing. It is not, machine learning is a tool. Any craftsman knows that you need to use the right tool for the job. Using the wrong tool will leave you unsatisfied[405]. Ultimately, what you create will either work or it will not work to achieve your objectives.

7.12. Models

Without a model you have an undifferentiated mass of data where there is no way which data can or should interact with other data. A model has little or no significance without the data to describe that model. But put the data and the model together and you get a dynamic web of information that seems almost magical.

Any large group trying to understand a complex phenomenon will find that process challenging. Models helps areas of knowledge make sense of unorganized information.

A model is an abstract description of something that hides certain unimportant details and illuminates other important details. Models help a group trying to

[404] Kalev Leetaru, *Our Entire AI Revolution Is Built On A Correlation House Of Cards*, https://www.forbes.com/sites/kalevleetaru/2019/04/20/our-entire-ai-revolution-is-built-on-a-correlation-house-of-cards/

[405] Gil Press, *This Week In AI Stats: Up To 50% Failure Rate In 25% Of Enterprises Deploying AI*, Forbes, https://www.forbes.com/sites/gilpress/2019/07/19/this-week-in-ai-stats-up-to-50-failure-rate-in-25-of-enterprises-deploying-ai/

describe an area of knowledge to do so effectively. Models do achieve this in the following important ways:

1. Models help groups of people in an area of knowledge to communicate.
2. Models describe, explain, and make predictions about that area of knowledge.
3. Models describe primitive phenomenon. Those primitive descriptions can then be used to describe complex phenomenon that is based on the primitive descriptions.
4. Models provide a way to orchestrate and mediate when you have multiple viewpoints. It is hard enough to get any two people to agree completely agree about something, let alone a significantly larger group. Models help groups represent commonalities while also understanding and exploring their differences.

Formal models are used in many different areas of knowledge when precision and objectivity are necessary. Models are not "black-and-white". Models organize human thought. Good models offer flexibility where flexibility is necessary.

A model is effectively a logical system. Let's walk you through a simple explanation of a logical system and how you can use a theory to describe such a system.

7.13. Metamodel

A metamodel is a model of a model. A financial reporting example will explain. Suppose that Microsoft represented its financial report in the form of a model. Now, suppose that Apple represented its financial report in the form of a model also. But what happens if Microsoft and Apple used different models to represent each of their financial reports?

That is where a metamodel comes in.

A regulator like the U.S. Securities and Exchange Commission (SEC) or the European Single Market Authority (ESMA) define a metamodel that the report models of companies submitting reports to the regulators must follow. That metamodel helps to make sure that the report model of each company report is consistent.

Could the SEC and ESMA use different metamodels? Sure. But also, could the SEC and ESMA use the same metamodel? Sure, that is possible too. Effectively, what the *Seattle Method* and *Standard Business Report Model* (SBRM) do is specify a metamodel that is consistent for both the SEC and ESMA XBRL-based digital financial reports.

7.14. SBRM and Seattle Method

The Object Management Group (OMG) is taking XBRL-based business reports to a new level, leveraging what has been learned from creating XBRL-based financial reports over the past 10 years. The *Standard Business Report Model* (SBRM)[406] is described as follows:

[406] *Object Management Group and Standard Business Report Model (SBRM)*, http://xbrl.squarespace.com/journal/2019/6/25/object-management-group-and-the-standard-business-report-mod.html

"SBRM formally documents a logical conceptualization of a business report in both human-readable and machine-readable models."

SBRM goes on to explain that through the use of standard models, business experts can define the structure and content of their reports and extensions using high-level logical business report objects, possibly presented in the form of semantic spreadsheets and pivot tables rather than with lower level technical syntax.

While XBRL has mainly been employed for financial reporting, leveraging the nature of financial accounting rules[407]; digital business reporting will benefit from the capabilities pioneered by XBRL-based financial reporting. Further, business reporting will not be limited to only one syntax but rather the arbitrary preferred syntax of can be used and systems can still be consistent with one conceptual model of a business report.

Financial reporting will likewise benefit from SBRM because SBRM helps business professionals and technical professionals constructing systems where flexible reporting is a requirement to effectively control variability and still have high-quality information exchanges.

SBRM is based on the ideas of the *Seattle Method*[408]. The *Seattle Method* is a proven, industrial strength, good practices based, standards-based pragmatic approach to creating provably high quality XBRL-based general purpose financial reports that builds on the Venetian Method of double entry bookkeeping and adapting it for the information age explained in simple terms approachable by business professionals.

7.15. Simple Explanation of a Logical Systems

A system can be explained by a logical theory. A logical theory is an abstract conceptualization[409] of specific important details of some area of knowledge. The logical theory provides a way of thinking about an area of knowledge by means of deductive reasoning to derive logical consequences of the logical theory.

A **logical theory** enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

A logical theory forms a **logical conceptualization** and is made up of a set of logical *models*, *structures*, *terms*, *associations*, *rules*, and *facts*. In very simple terms,

- **Logical conceptualization**: A *logical conceptualization* is a set of models that are consistent with and permissible per that logical conceptualization.
- **Model**: A *model*[410] is a set of logical structures that are consistent with and permissible interpretations of that logical conceptualization.
- **Structure**: A *structure* is a set of logical statements which describe the structure.

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[407] Charles Hoffman, *Leveraging the Theoretical and Mathematical Underpinnings of a Financial Report*, http://xbrlsite.azurewebsites.net/2018/Library/TheoreticalAndMathematicalUnderpinningsOfFinancialReport.pdf

[408] Seattle Method, http://xbrlsite.com/seattlemethod/SeattleMethod.pdf

[409] Wikipedia, *Conceptual Model*, https://en.wikipedia.org/wiki/Conceptual_model

[410] Wikipedia, *Model Theory*, https://en.wikipedia.org/wiki/Model_theory

- **Logical statement**: A *logical statement* is a proposition, claim, assertion, belief, idea, or fact about or related to the area of knowledge to which the logical conceptualization relates. There are five broad categories of logical statements:
  - **Terms**: *Terms* are logical statements that define ideas used by the logical theory such as "assets", "liabilities", "equity", and "balance sheet".
  - **Associations**: *Associations* are logical statements that describe permissible interrelationships between the terms such as "assets is part-of the balance sheet" or "operating expenses is a type-of expense" or "assets = liabilities + equity" or "an asset is a 'debit' and is 'as of' a specific point in time and is always a monetary numeric value".
  - **Rules**: *Rules* are logical statements that describe what tend to be convertible into IF…THEN…ELSE types of relationships such as "IF the economic entity is a not-for-profit THEN net assets = assets - liabilities; ELSE assets = liabilities + equity".
  - **Facts**: *Facts* are logical statements about the numbers and words that are provided by an economic entity within a business report. For example, the financial report, a type of business report, might state "assets for the consolidated legal entity Microsoft as of June 20, 2017 was $241,086,000,000 expressed in US dollars and rounded to the nearest millions of dollars.
  - **Properties**: *Properties* are logical statements about the important qualities and traits of a model, structure, term, association, rule, or fact.

Fundamentally, a logical theory is a set of logical statements. Those logical statements can be represented in human-readable form or they could be expressed in machine-readable form. Once in machine-readable form, those logical statements can be interrogated using software applications. To the extent that this can be performed effectively; software tools can assist professional accountants, financial analysts, and others working with those logical statements.

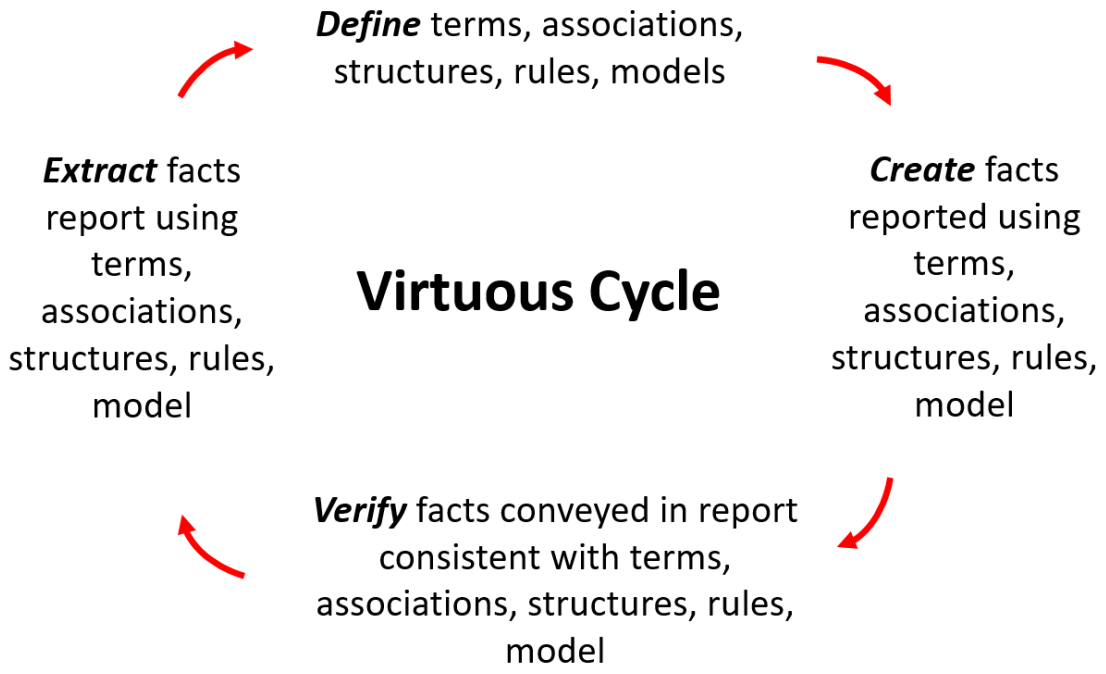
7.16. Proper Functioning Logical System

A logical system is said to be **consistent** with a logical theory if there are no contradictions with respect to the logical statements made by the logical theory that describes the logical system.

A logical theory can have high to low **precision** and high to low **coverage** with respect to describing a logical system.

Precision is a measure of how precisely the information within a logical theory has been represented as contrast to reality of the logical system for the area of knowledge. *Coverage* is a measure of how completely information in a logical theory has been represented relative to the reality of the logical system for the area of knowledge.

When a logical system is consistent and it has high precision and high coverage the logical system can be considered a **properly functioning logical system**. When a logical system is properly functioning, it creates a virtuous cycle[411].



A logical theory conveys knowledge and that knowledge can be represented within a knowledge graph.

7.17. Very Simple Example of Logical System

A very simple example of a logical system is the accounting equation[412]. Here is a description of the accounting equation logical system in both human-readable terms and machine-readable terms using XBRL[413]:

Terms: Three simple terms are defined: Assets, Liabilities, Equity. One complex term is defined, balance sheet.

Structure: One structure is defined, the balance sheet, and identified using the term balance sheet.

Associations: The three terms Assets, Liabilities, and Equity are associated in that they are all PART-OF the structure balance sheet.

Rules: A mathematical assertion is made that "Assets = Liabilities + Equity".

Facts: Instances of three facts are established to exercise the model: Assets of $5,000; Liabilities of $1,000; Equity of $4,000.

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411 Charles Hoffman, CPA, *Virtuous Cycle*, http://xbrl.squarespace.com/journal/2020/4/29/virtuous-cycle.html
412 Wikipedia, *Accounting Equation*, https://en.wikipedia.org/wiki/Accounting_equation
413 Charles Hoffman, *Accounting Equation*, http://xbrlsite.azurewebsites.net/2020/master/ae/

Model: All of the terms, associations, assertions, structures, and facts describe the model. We created only one model, or permissible interpretation, of the logical theory. (As accountants know, if you reverse the equation using the rules of math to "Equity = Assets - Liabilities" and change the term "Equity" to "Net Assets"; then you get another permissible interpretation or model.)

Because this is a very simple example with only a few statements it is easy to get your head around this system and see that it is consistent, complete, and precise. As expected, you see three facts described by three terms which are related to one structure and the one rule is consistent with expectation:

Balance Sheet [Abstract]	Period [Axis]
	2020-12-31
Balance Sheet [Abstract]	
Assets	5,000
Liabilities	1,000
Equity	4,000

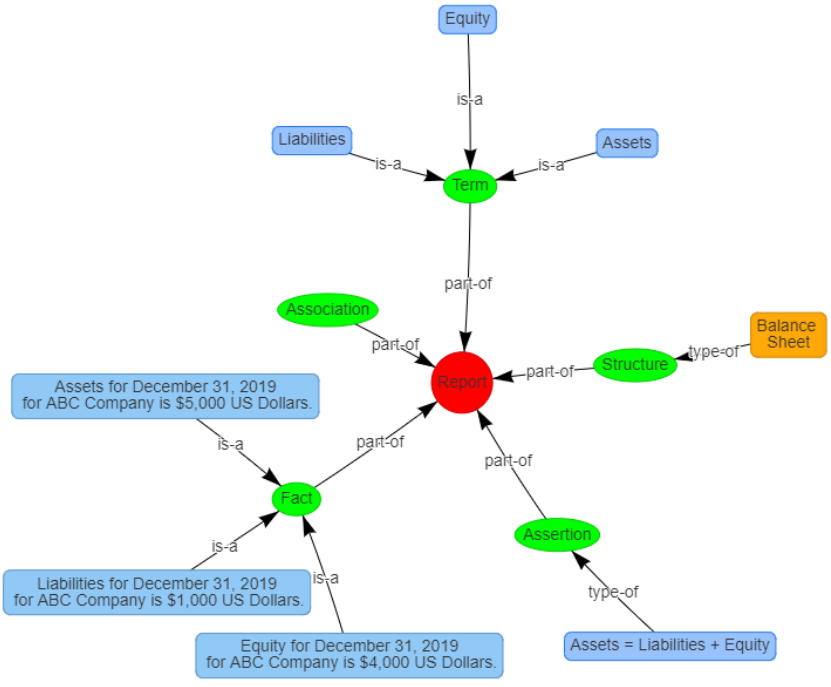
Balance Sheet

Consistent
Complete
Precise
1

Assets = 5,000
Liabilities = 1,000
Equity = 4,000
Assets = Liabilities + Equity

Result	Rule
Pass	$Assets = $Liabilities + $Equity

As the size of the logical system increases it becomes increasingly more challenging to verify that the logical system is properly function using manual processes. But, covering the impediments to a properly functioning logical system are beyond our scope here[414]. Essentially, the models, terms, structures, rules, and facts form a directed acyclic graph such as:



[414] Charles Hoffman, CPA, *Impediments to Creating Properly Functioning XBRL-based Reports*, http://xbrlsite.azurewebsites.net/2020/core/master-ae/Documentation.pdf

While a typical financial report is significantly larger (i.e. the Microsoft 2017 10-K is made up of 194 structures) every financial report works the same as this very simple example but just has more pieces[415].

7.18. Semantic Glue

Effectively, what a logical digital twin provides is the "semantic glue[416]" that hooks the pieces of information within the logical digital twin together and also lets you reference that logical information. Rather than referencing a position in a spreadsheet, you reference information based on the information logic of that information.

7.19. Complexity

A kluge is a term from the engineering and computer science world that refers to something that is convoluted and messy but gets the job done. Elegance is the quality of being pleasingly ingenious, simple, neat. Elegance is about beating down complexity. Creating something complex is easy. Creating something simple and elegant is hard work.

The *Law of Conservation of Complexity* points out,

"Every application has an inherent amount of irreducible complexity. The question is who will have to deal with that complexity: the application user, the application developer, or the platform developer that the application runs on."

Complexity cannot be removed from a system; but it can be moved. The terms "simplistic" and "simple" describe different things. Simplistic is dumbing down a problem in order to make the problem easier to solve. Simple is something that is not complicated, that is easy to understand or do. Simple means without complications.

7.20. Irreducible Complexity

Irreducible complexity[417] is a term used to describe a characteristic of complex systems whereby the complex system needs all of its individual component systems in order to effectively function. In other words, it is impossible to reduce the complexity of a system (or to further simplify a system) by removing any of its component parts and still maintain its functionality objective.

The semantic web stack or "layer cake"[418] helps one understand all the pieces that are necessary to implement a compete problem solving system. This graphic generalizes those pieces, trying to separate the problem from the implementation of technology to solve the problem:

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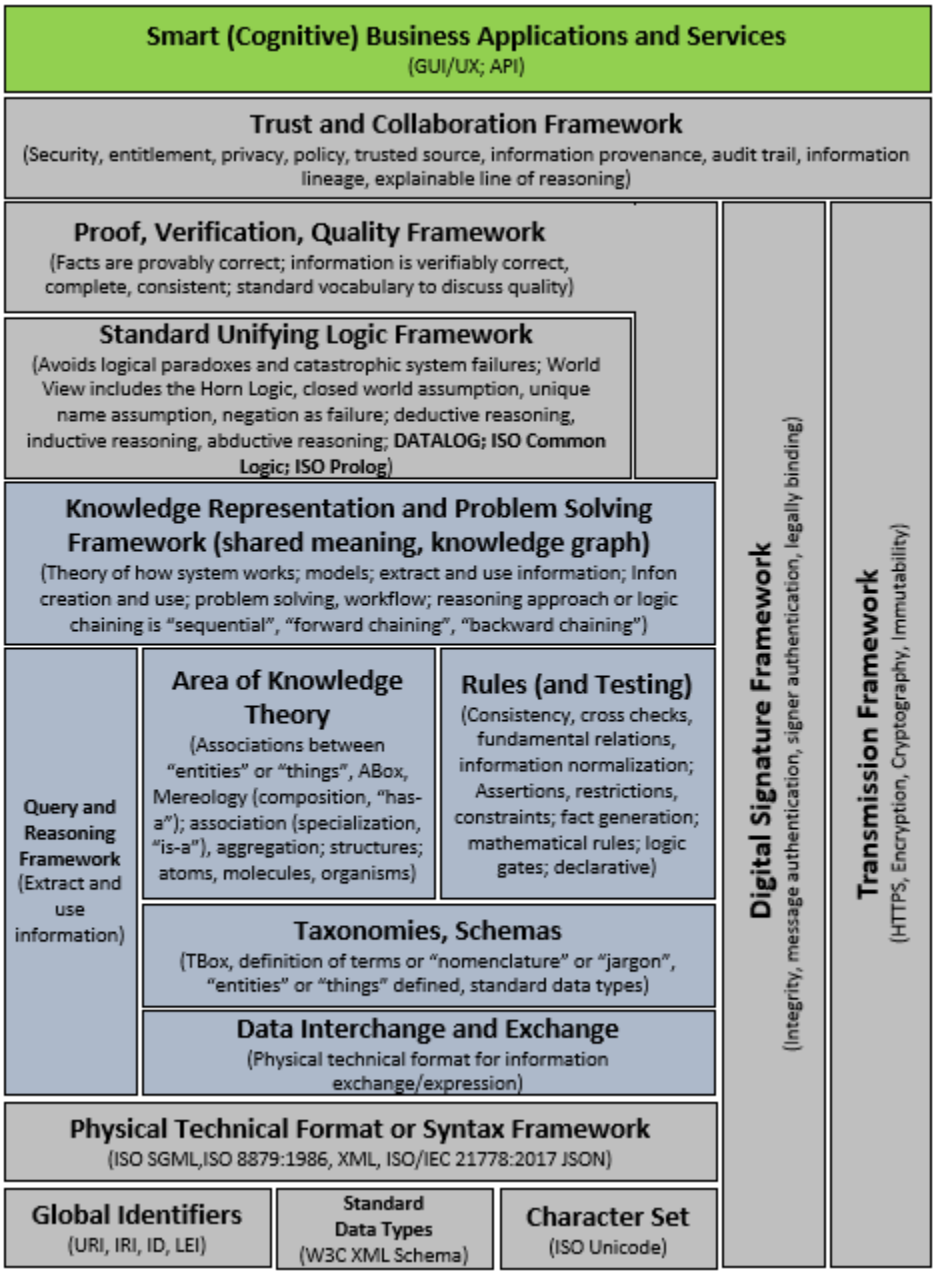
[415] *Analysis of 6,751 XBRL-based Public Company 10-Ks Submitted to SEC*, http://www.xbrlsite.com/mastering/Part05_Chapter08.F_AnalysisOf675110Ks.pdf

[416] *Understanding and Leveraging the "Semantic Glue" of XBRL-based Financial Reports*, http://xbrlsite.com/2024/Library/UnderstandingAndLeveragingSemanticGlue.pdf

[417] *Smart (Cognitive) Business Applications and Services*, https://digitalfinancialreporting.blogspot.com/2024/02/smart-cognitive-business-applications.html

[418] *Semantic Web Stack or Layer Cake*, https://medium.com/openlink-software-blog/semantic-web-layer-cake-tweak-explained-6ba5c6ac3fab

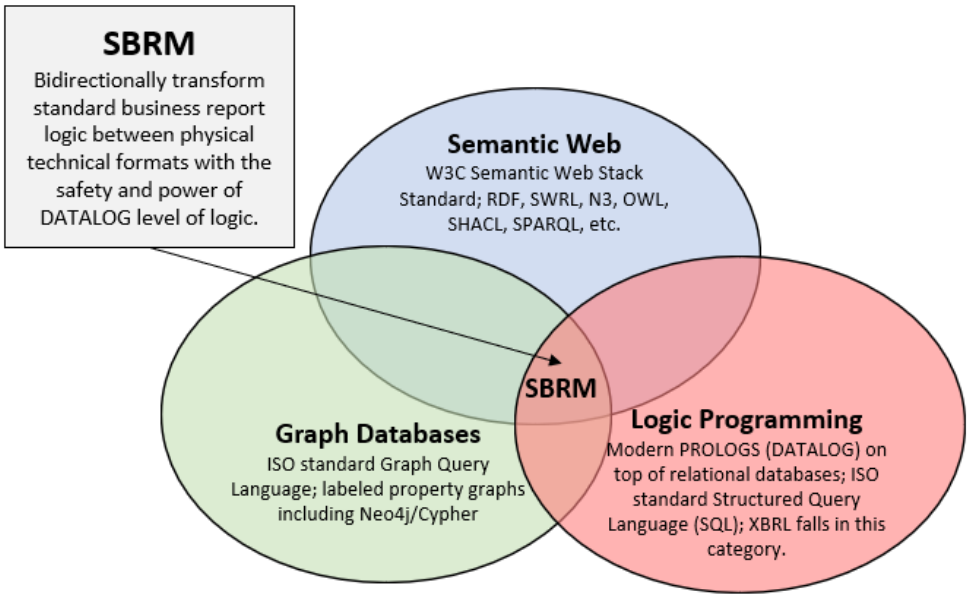


7.21. Implementing Logical Systems

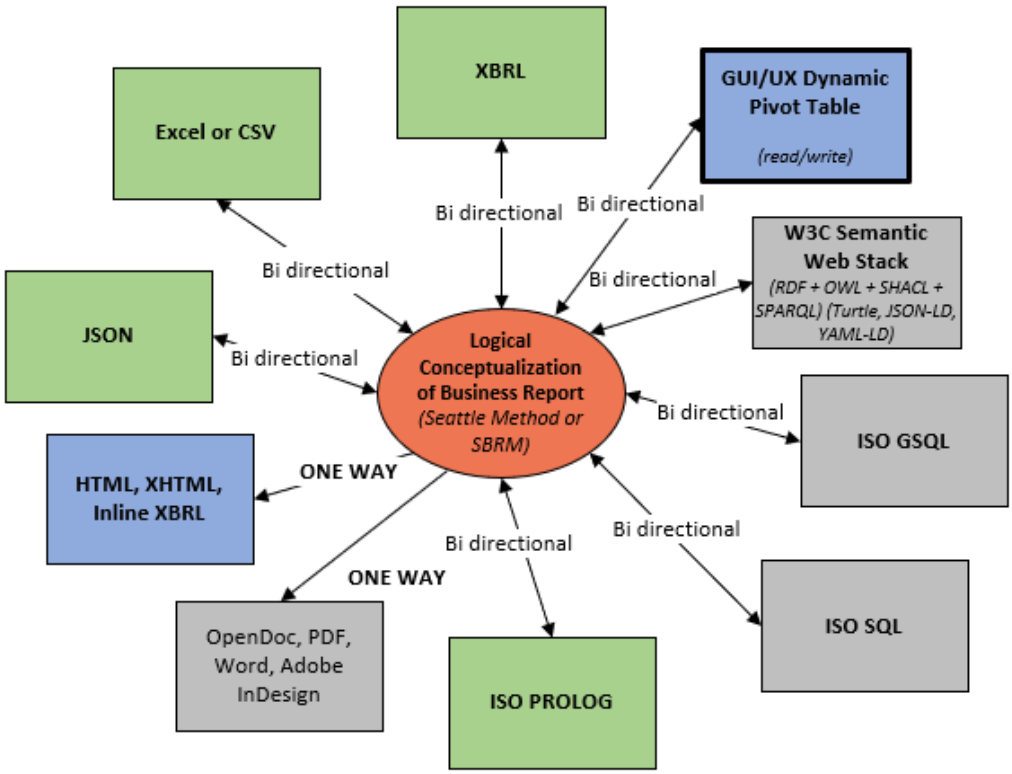
There tends to be three primary logical system (a.k.a. problem solving system) implementation approaches:

- Semantic web stack
- Graph database
- Logic programming

This graphic below shows the three approaches and makes an important point. The Standard Business Report Model (SBRM) logical conceptualization is an approach to enabling the conversion between these three technical implementation approaches.

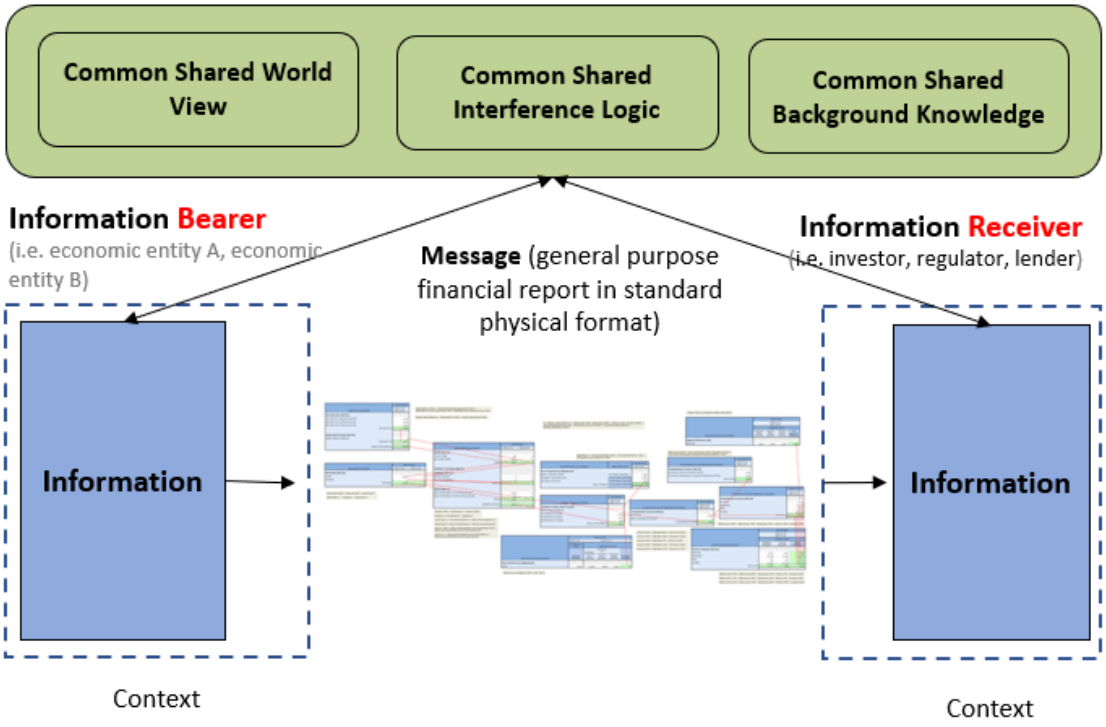


And so, the Standard Business Report Model (SBRM) enables the conversion of the logic of a business report (such as a financial report) between different technical implementations.



7.22. Effective Information Exchange Between Logical Systems

The following graphic shows what is necessary in order to exchange information effectively between two different logical systems.



8. Representing Knowledge

This section provides important information about representing knowledge.

8.1. Sensemaking

Sensemaking[419] is the process of determining the deeper meaning or significance or essence of the collective experience for those within an area of knowledge. Systems evolve over time[420].

Some professional accountants need to develop the skills to represent things digitally[421]. A Wardly Map is a sensemaking tool.

A Wardley Map is a sketch. Usually of a business, market, or any other kind of work system. A Wardly Map is a design, like a blueprint. The Wardly Map might be right, it might be wrong; but it is something that can discussed and refined together on paper to make sure everything we do in reality is as purposeful as it can be. These designs will inevitably be put to the test. No one is exempt; not even governments

[419] Sensemaking, http://xbrl.squarespace.com/journal/2021/11/18/sensemaking.html
[420] *Evolution of a System*, http://xbrlsite.com/2023/Library/EvolutionOfSystem.pdf
[421] Skills to Represent Things Digitally, https://digitalfinancialreporting.blogspot.com/2023/02/skill-to-represent-things-digitally.html

or non-profits. So, to help us cope, we acknowledge this fact up front by arranging our blueprint by evolutionally stage; from the uncharted where things are uncertain, high failure, and a gamble; to the industrialized where things are known, reliable, and standard practice. Awareness of these qualities helps us approach each part of the system deliberately. No "one size fits all", only careful specific intention. But the map is only the beginning. Behind Wardley Mapping is a deeper strategic thinking process. There are many patterns to learn, principles to practice, and moves to make. Take it one step at a time for even the smallest insight can change everything

8.2. Formalism

A formalism is the practice of using strict and complete methods to define and specify the important essence of a model. Every term in the formalism is given precise a definition. Every variable, parameter, rule, and factor are given a precise name and definition. A formalism stives to be complete and precise definition of the model and its mechanisms which are being described, ideally with no redundancy or gaps.

Logic and knowledge graphs (a.k.a. semantic networks[422]) are formalisms for describing information.

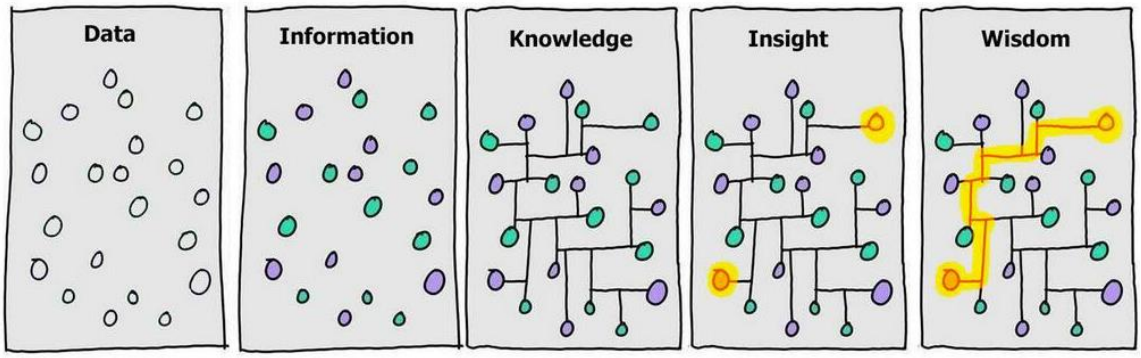
8.3. Information is Data in Context

There are specific differences between data, information, knowledge, and wisdom[423]: (note that I have added insight to match with the graphic which is shown next)

- **Data**: The basic compound for intelligence is data. Data are measures, observations, symbols, phenomenon, utterances, and other such representations of the world around us presented as external signals and picked up by various sensory instruments and organs. *Simplified: data is raw facts and numbers*.
- **Information**: Information is produced by assigning relevant meaning related to the context of the data to the data. *Simplified: information is data in context*.
- **Knowledge**: Knowledge is the understanding or interpretation, a justifiable true belief, of information and approach to act upon the information in the mind of the perceiver. *Simplified: knowledge is the interpretation of information*.
- **Insight**: Insight is the first step in putting information and knowledge to work for you.
- **Wisdom**: Wisdom embodies awareness, insight, moral judgments, and principles to construct new knowledge and improve upon existing understanding. *Simplified: wisdom is the creation of new knowledge*.

The following graphic perhaps provides the best visual explanation as to the difference between data, information, knowledge, insight, and wisdom[424] that I have run across:

[422] Wikipedia, *Semantic Network*, https://en.wikipedia.org/wiki/Semantic_network
[423] Wikipedia, *DIKW Pyramid*, https://en.wikipedia.org/wiki/DIKW_Pyramid



Decision = Data + Knowledge

Ontology = Terms + Associations

Knowledge = Ontology + Rules

Algorithm = Logic + Control

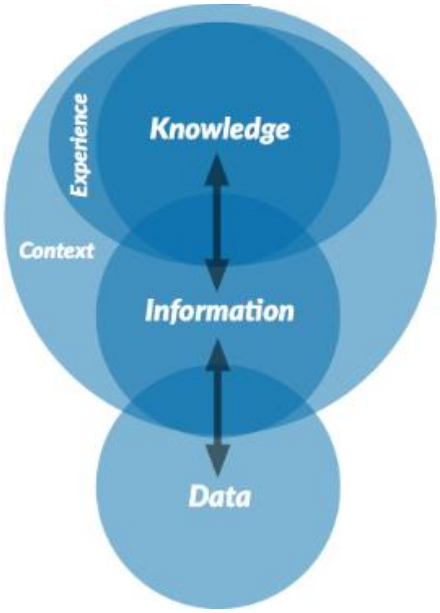
The difference between *data* and *information* is that data is the raw numbers and words where information is data in context. This is important to understand as most problems faced by accountants are an information problem, rather than a data problem. Getting data is easy. Knowing what that data represents and how the data fits together is more difficult. Representing information in the form that a machine such as a computer can understand and use that information safely and effectively is difficult.

Knowledge is a set of data and information and a combination of skill, know-how, experience which can be used to improve the capacity to take action or support a decision making process.

Insight and wisdom are related to putting information and knowledge to work for you.

The following graph created by Shawn Riley shows the important to understand differences between data, information, and knowledge[425].

[424] Tumblr, *Information isn't Power*, https://random-blather.com/2014/04/28/information-isnt-power/
[425] Shawn Riley, *Machine Learning versus Machine Understanding*, https://www.linkedin.com/pulse/machine-learning-vs-understanding-shawn-riley/

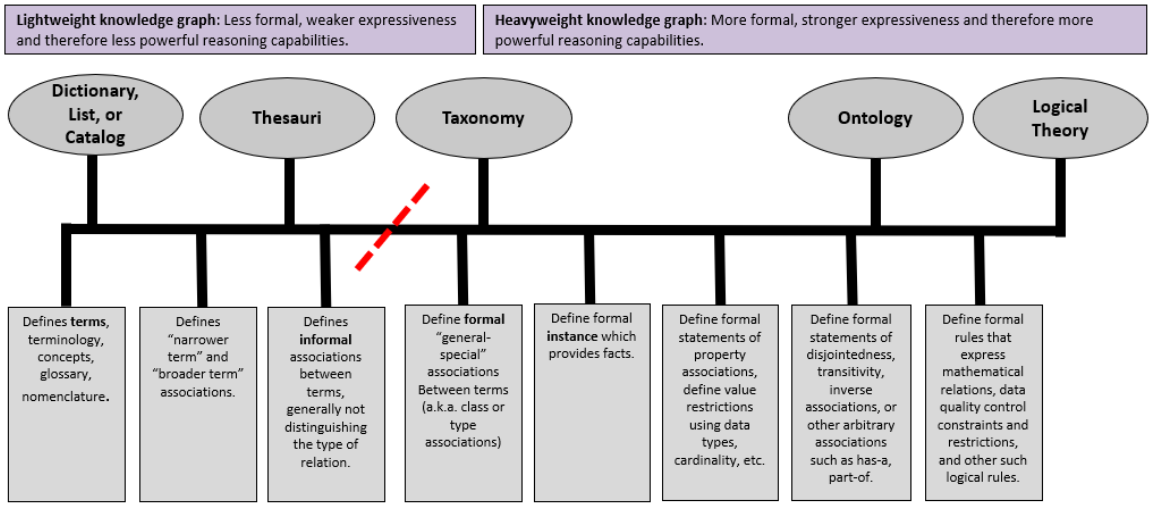


The important point to understand here is that it takes the skill and experience of human professionals to create information and knowledge and to put that knowledge into the proper context.

Our focus here is information, not data.

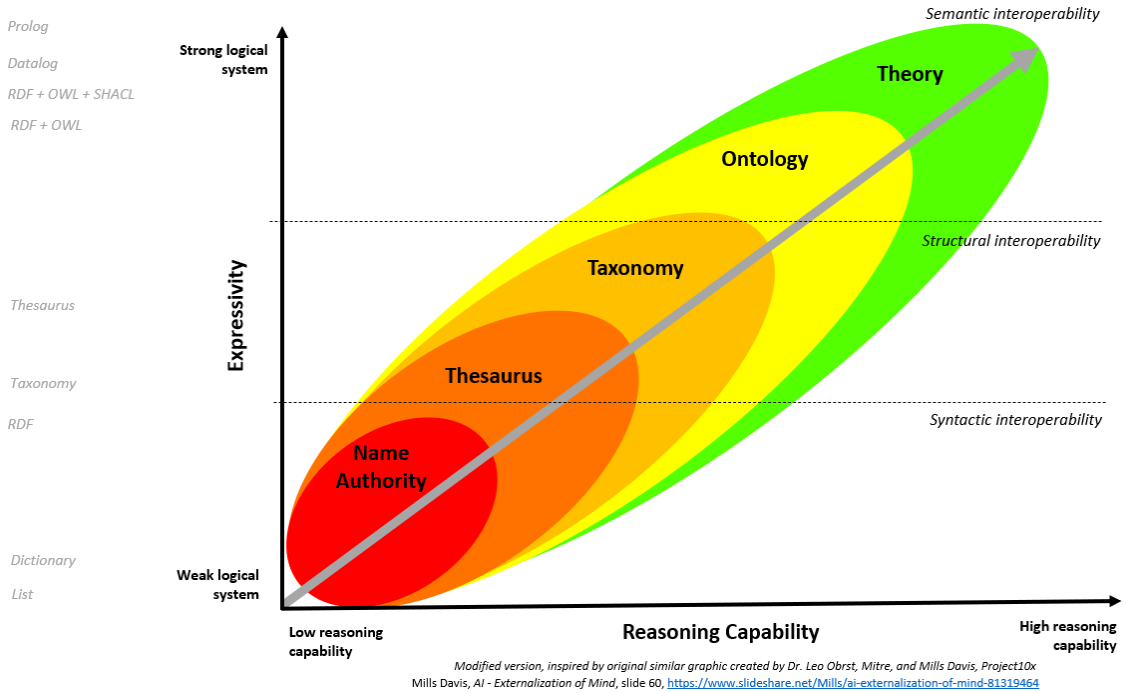
8.4. Tools for Representing Knowledge

There are a number of different tools that can be used to effectively represent knowledge in the form of a knowledge graph. Below you see a spectrum of such tools with the least powerful tools on the left and increasing in power to the right:



Inspired primarily by Deborah L. McGuinness, *Ontologies for the Modern Age,* Slide 4, https://www.slideshare.net/deborahmcguinness/ontologies-for-the-modern-age-mcguinness-keynote-at-iswc-2017

Another version of the information above is this graphic:



When representing knowledge, the right tool should be used for the job. A logical theory is the easiest way to enable business professionals to understand a logical system because business professionals have an innate understanding of logic. I will refer to these tools as ontology like things.

8.5. Practical Ontology Like Things

There are many definitions/descriptions of 'ontology'[426]. One good definition/description of an ontology is as a "formal, explicit specification of a shared conceptualization." [427]

My working definition/description of an ontology like thing is a formal, explicit specification of an intended shared conceptualization in logic for an area of knowledge to achieve some specific set of goals/objectives."

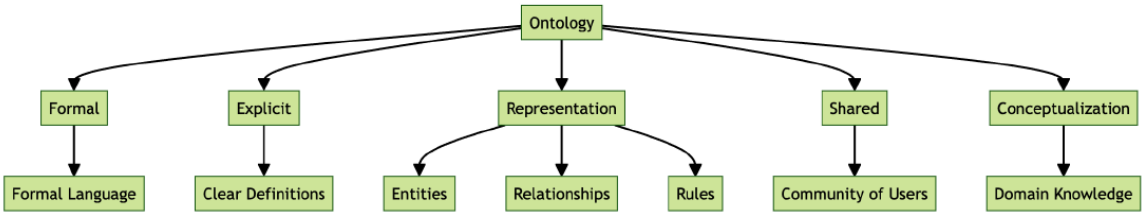
The precise definition of the word ontology and which term you use to describe that representation is less important than the intent of the representation. The way to test a conceptualization and the specific logic of that conceptualization is via testing.

The language or physical technical format used to represent the logic of the conceptualization described/defined by the ontology like thing is a different issue. Global standard technical formats are preferred to proprietary formats.

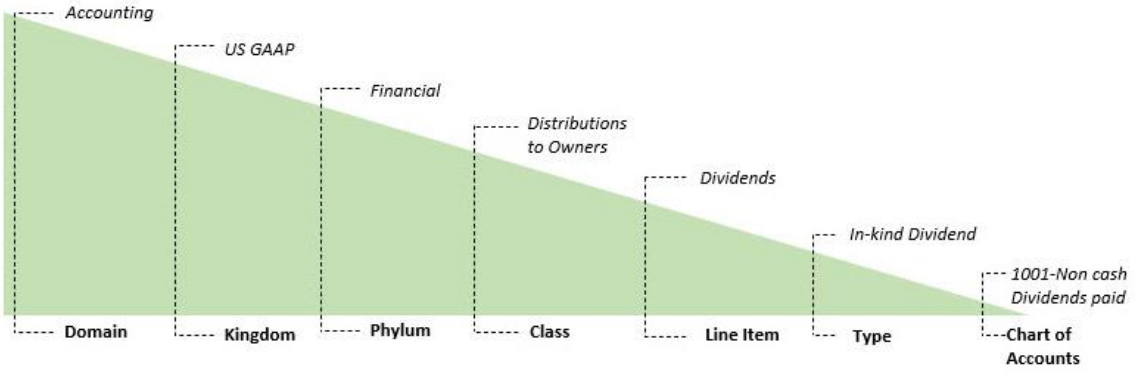
But the ultimate test of an ontology like thing is testing to prove that the logic of the conceptualization works.

The graphic below describes the sorts of things that need to be represented and other decisions which need to be made to express a conceptualization:

[426] Arxiv.org, Fabian Neuhaus, *What is an Ontology?,* https://arxiv.org/pdf/1810.09171
[427] National Library of Medicine, *Understanding Ontologies*, https://www.ncbi.nlm.nih.gov/books/NBK584339/



The major taxonomic ranks and classifications can vary[428].



As a tool, the limitations of the tool must be understood in order to employ the tool effectively. Common criticisms and discussions related to the notion of an ontology include:

- **Vagueness and ambiguity**: Anything created by humans tends to not be perfect. What exactly constitutes a "conceptualization"? What does "explicit specification" actually mean; that might vary significantly between different contexts.
- **Scope and scalability**: An ontology like thing should cover all the necessary aspects of some area of knowledge. Trying to get an ontology like thing to do everything can be challenging. This is why defining the goals and objectives of the intended use of an ontology like thing is important.
- **Adaptability**: Knowledge is fluid, dynamic; not static. The world changes, ontology like things need to be adaptable to that changing world. But ontology like things can tend to be static. Rather, an ontology like thing needs to be adaptable to dynamic environments where new information needs to be integrated into a system continuously.
- **Context-dependency**: Context is important. What works in one area of knowledge might not work in some other area of knowledge. Transferability of an ontology from one intended purpose to some other intended purpose or generalizing the ontology like thing may not work.
- **Bias**: Human bias in any ontology like thing must be understood and managed. Certain ontology like things might not be suitable or optimal for computational systems. Human bias can limit the design and functionality of ontology like things intended for use by artificial intelligence type applications.

[428] Wikipedia, *Taxonomic Rank*, https://en.wikipedia.org/wiki/Taxonomic_rank

- **Interoperability**: Many times, ontology like things are meant to solve interoperability problems within systems through the creation of a shared, common understanding; reality is often more complex. Different ontology like things might interpret the same concepts in different ways, leading to difficulties in integrating systems or data that use different frameworks.

These and other criticisms and discussions will continue. A master craftsmen must have a good understanding of the limitations of their tools. Criticisms and discussions lead to refinement of the tools. Use of these tools over time will push the tools towards more dynamic, interoperable, adaptable, context-aware systems.

8.6. Knowledge Graph

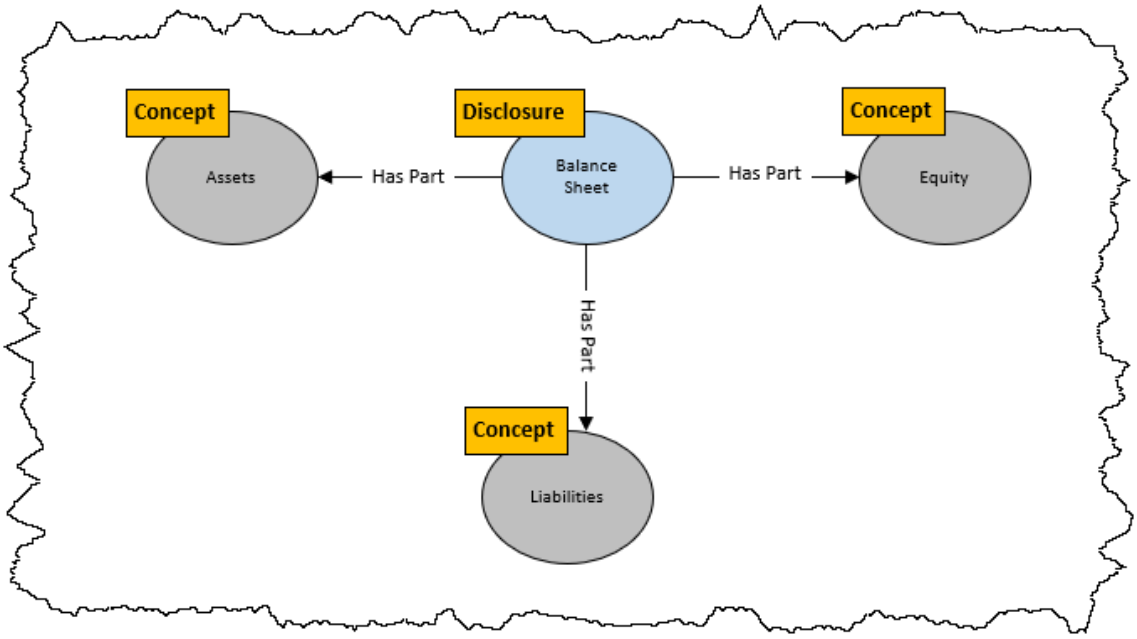
We communicate using knowledge graphs. When you go to a whiteboard and draw circles and squares and connect them with lines with arrows you are drawing a graph and communicating knowledge. Those circles, squares, lines, and arrows are intuitively understandable and very expressive. These informal knowledge graphs like this have been used by humans to communicate information for quite some time. The earliest documented use of knowledge graphs (a.k.a. semantic networks) was the third century CE.

Knowledge is the understanding or interpretation of information. Knowledge relates to terms, structures, associations, rules, facts, and skills acquired by a person through experience or education that relates to the theoretical or practical understanding of something.

A **graph**, in formal terms, is a set of vertices and edges. In less intimidating language, a graph is a set of nodes and the relationships that connect the nodes together. Graphs represent things as nodes and the ways in which those things relate to one another and rest of the world as relationships.

A graph is a general-purpose communications tool that allows us to model all sorts of scenarios in terms that are innately understandable to humans. One thing that can be represented in the form of a graph is knowledge.

This is a simple graph of knowledge, or a **knowledge graph**:



A knowledge graph[429], also known as a semantic network, represents a network of real-world things (entities)—i.e. objects, events, situations, or concepts—and illustrates the relationship between them. This information can be visualized as a graph structure.

8.7. Graphs

When I use the term graph, I am referring to the term in the context of graph theory[430] which is a discipline of mathematics. Wikipedia's definition of graph theory and graph is:

In mathematics, graph theory is the study of graphs, which are mathematical structures used to model pairwise relations between objects.

This is a very simple graph:

Just like most other things, graphs have a jargon. In formal graph jargon, the circles are referred to as an edge and the line is referred to as a vertex.

Others in other areas use different terminology to refer to exactly the same idea. Here are synonyms for the notions of *edge* and *vertex*:

Edge	Entity	Node	Point	Report element
Vertex	Relationship	Line	Path	Association

[429] IBM, *What is a Knowledge Graph?*, https://www.ibm.com/topics/knowledge-graph
[430] Wikipedia, *Graph Theory*, https://en.wikipedia.org/wiki/Graph_theory

A graph can have can have one or more paths between points; paths can have loops or cycles, circuits, as well as can have self-loops, and paths can go in one direction or both directions.

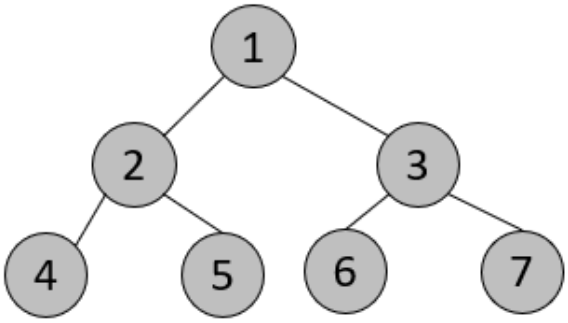
To better understand graphs, let's look at some subtle but very important differences between some different types of graphs.

If we take the time to consciously formalize the rules related to graphs and understand those rules these communications tools become more effective and they can even be understood by computer software applications.

8.8. Trees

A tree is a special type of graph. Most people are more familiar with trees than graphs. A tree is what is called an undirected graph because the items in a tree are connected by exactly one path. This is important to understand because it means that trees are safer than other types of graphs which can contain cycles. But trees have a limitation in that an edge can appear only once in a tree and a tree always has exactly one root edge. Also, because trees are undirected, they provide less information and so they are less powerful in terms of expressiveness.

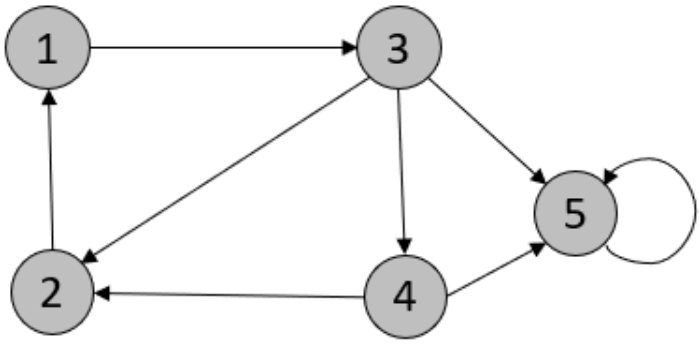
The following is an example of a graph that is also a tree:



Notice the root, node number 1 and that ever other node that appears is unique. Notice also that there is no direction associated with the lines that appear between the nodes.

8.8.1. Directed Graph

A directed graph is a special type of graph that provides a direction on each vertex. For example, below you see a directed graph: (notice the arrows)

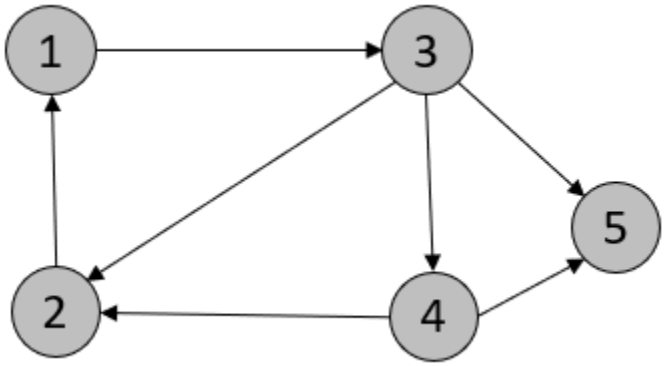


Note that each vertex (line) has an arrow that points in a specific direction; that is what makes the graph a directed graph. Note edge (node) number 5 which has an arrow that points to itself; that is a cycle. Cycles like that can cause issues such as causing an infinite loop. Those sorts of issues can be solved by using a directed acyclic graph that does not allow such cycles which we will cover next.

Directed graphs are more powerful than trees but because of the possibility of a cycles, they can be unsafe for certain things.

8.8.2.Directed Acyclic Graph

A **directed acyclic graph** (DAG) is an even more special type of graph that provides a direction on each vertex and you are guaranteed not to have any cycles in the graph. This makes the graph very save as there is not a possibility of creating infinite loops that can break software applications. For example, below you see a directed acyclic graph:



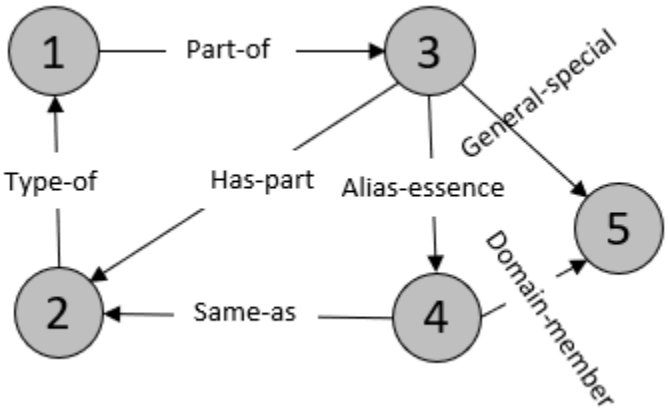
Note again that each vertex has an arrow which specifies a direction and that there are no cycles making this a directed acyclic graph. Note that there is not one specific edge (node) that can be considered the root of the graph.

But note that you don't have any information about the nature of the vertices (lines). What if information was provided about the relationships in the graph as communicated by the vertices (lines)?

8.8.3.Labelled Directed Acyclic Property Graph

A labeled directed acyclic property graph specifies a type of vertex for each association between any two edges. Specifying that feature, the nature of the relationship, provides additional information that is useful in working with a graph.

For example, below you see a labeled directed acyclic graph: (notice the labels on the arrows)



Note the labels that explain each vertex in the graph. You can, for example, query a graph for those relationship types. Labeled directed acyclic graphs have the most power in terms of expressiveness but are also very safe to use because they are guaranteed not to contain any cycles which can lead to catastrophic failure when read by a machine-based process.

8.8.4.Typed Directed Acyclic Property Graph

Now I am getting over my head, but this seems to have a profoundly important impact on functionality and query speed. There seems to be a difference between a "labeled property graph" and a "typed property graph". Also, there seems to be a critically important difference between RDF graphs and graph databases. Seems that RDF graphs are typed, but you cannot add properties. Seems that labeled property graphs are more flexibly, but that flexibility might not be needed and it impacts functionality and query speed.

This is maddeningly difficult for a business professional to understand. But, reading this article *Labeled vs Typed Property Graphs — All Graph Databases are not the same*[431] and understanding TypeDB[432] are important. Strongly typed graph databases seem very compelling. "TypeDB provides a strong type system for developers to break down complex problems into meaningful and logical systems. Through TypeQL, TypeDB provides powerful abstractions over low-level and complex data patterns."

This seems like incredibly important stuff but I don't really understand it as well as I would like to. And frankly, most software engineers don't seem to understand it well either which makes this problematic. Finally, how does something like PROLOG fit into this comparison.

8.8.5.Knowledge Graph with a Logical Schema

Suppose that you have a strongly typed acyclic labelled property graph of semantic knowledge; but the knowledge in that knowledge graph is incomplete, it does not accurately or precisely represent the logic of an area of knowledge, and the logic

[431] Medium, *Labeled vs Typed Property Graphs — All Graph Databases are not the same*, https://medium.com/geekculture/labeled-vs-typed-property-graphs-all-graph-databases-are-not-the-same-efdbc782f099
[432] Vaticle, Strongly Typed Database, https://vaticle.com/

within that knowledge graph was inconsistent, contradicting itself. How useful is that?

And that is why it is important to provide a logical schema to verify that the information contained within a knowledge graph is consistent with expectation, is complete, and is precise. This is why you want a professional quality knowledge graph.

8.9. Professional Knowledge Graphs

Strongly typed directed acyclic labelled property graph of semantic knowledge which includes a logical schema are the knowledge representation tool of professional master craftsmen[433].

This describes each of the carefully used words that I have selected and used above. Notice that there is nothing about which syntax is used to physically represent that type of knowledge graph.

- "**Graph**" in knowledge graphs as contrast to the notion of a "tree" which is a type of graph which is not as flexible. So a knowledge GRAPH as contrast to a knowledge TREE is more flexible should you need that flexibility and many business use cases need that flexibility. (This explains the difference between a graph and a tree.)
- "**Directed**" as contrast to "undirected"; directed graphs can specify a direction of a relationship whereas undirected graphs do not. (This explains the difference between directed and undirected graphs.)
- "**Acyclic**" graphs do not contain cycles as contrast to a "cyclic" graph that does contain cycles. Cycles can be problematic and cause catastrophic processing failures such as an infinite loop. Graphs with cycles can cause logical paradoxes as I understand it and therefore cycles in graphs are to be avoided. (This explains the difference between acyclic and cyclic graphs.)
- "**Property**" graphs allow you to formally express properties on a relationship (a.k.a. edges) as contrast to only being able to provide properties for "entities" or "things" (a.k.a. nodes). Since the properties expressed provide more information, property graphs can be more powerful in terms of processing capabilities. (This explains property graphs.)
- "**Typed**" graph systems provide a formal system of typing properties and subtyping. This is as contrast to untyped graphs which do not. Typed graph theory explains the details. Another term for this is the notion seems to be strong typing. And yet another term seems to be static typing versus dynamic typing. The graph database TypeDB explains why typing is important.
- "**Labeled**" graphs have explicit, distinct identifiers while unlabled graphs do not. See this explanation of labeled graphs and unlabled graphs. It is unclear to me whether a graph can be both labeled and typed. This seems to imply that you get one or the other.

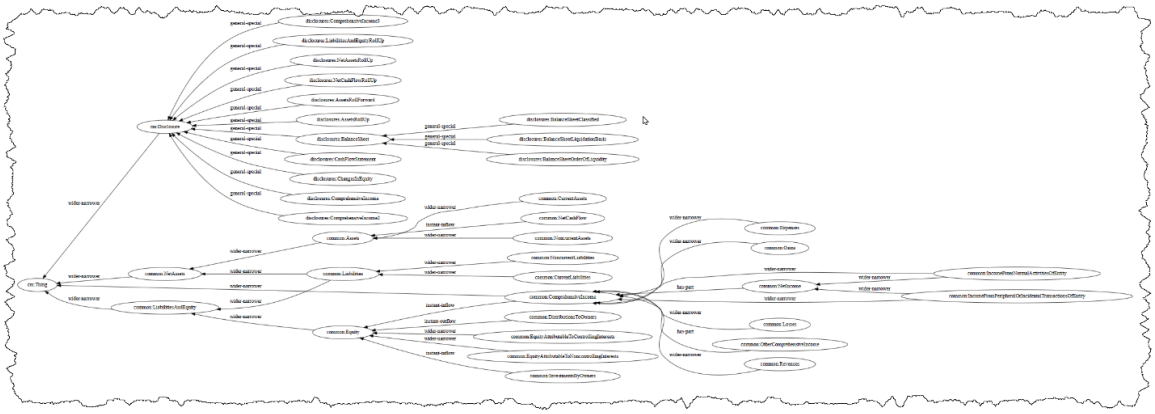
[433] Professional Knowledge Graphs, https://digitalfinancialreporting.blogspot.com/2023/12/professional-knowledge-graphs.html

- "**Semantic**" graphs are can provide models of meaning as contrast to other knowledge graphs which are for something different such as the presentation of information within sheets, rows, columns, and cells of a spreadsheet. When I am talking about knowledge graphs it relates to business semantics or business logic, not presentation. For more information see, Semantic Graphs - an Introduction; All About Knowledge;
- "**Logical schema**" is similar to the schema of a database but far, far richer in terms of logical expression.

In addition to being a strongly typed directed acyclic labeled property graph of semantic knowledge and having a logical schema; one needs a rules engine to enforce the logic at the DATALOG level of logic. TerminusDB[434] seems to fit this bill.

8.10. Basic Example of Knowledge Graph

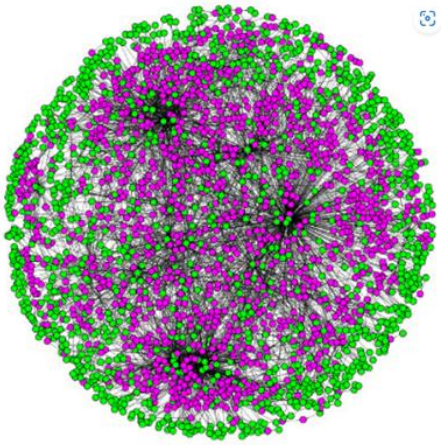
The following is an example knowledge graph that explains accounting information related to the four statement financial statement model[435]:



8.11. Generalized Knowledge Graphs (Graph Hairball)

When viewed in general terms; a knowledge graph system logic, the "things" and "relations between things" that graph theory calls "vertices" (a.k.a. nodes, points, entities, things) and "edges" (a.k.a. links, lines, relations, associations), looks like a big graph hairball as some people call it an example of which you can see here in the graphic below. This is because in order to work with any specific knowledge graph system of logic we need to look at that is common between the knowledge graph system which is the things and the types of relations between things.

[434] TerminusDB, Datalog Explanation, https://terminusdb.com/docs/datalog-explanation/
[435] Auditchain, *Four Statement Model Knowledge Graph*, https://auditchain.infura-ipfs.io/ipfs/QmTtcz3rcEmsSYjkev3Xo9qHH2YUrnkGimyt9Wq2YV3Lr2/typeSubTypeGraph.html

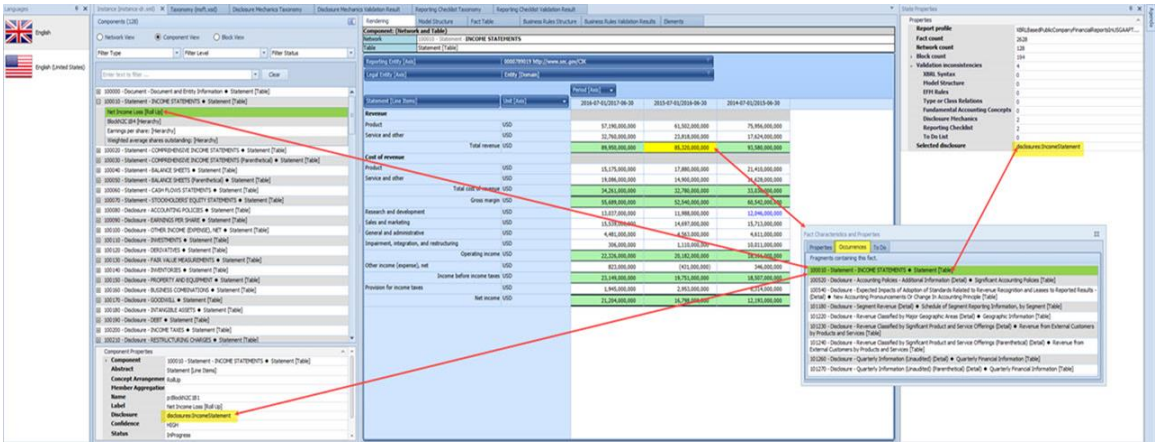


This view of the information in a knowledge graph can be useful for some things, but it is less useful for other things. In order to get a more useful view of the logic contained in a knowledge graph; we specialize the view to the specific application of the graph of knowledge that we are using.

By leveraging the specific high level logical mode of a specific type of knowledge graph system we can get a view of the knowledge graph system that is more useful to that specific area of knowledge.

8.12. Specialized Knowledge Graphs (e.g. Financial Report Knowledge Graph)

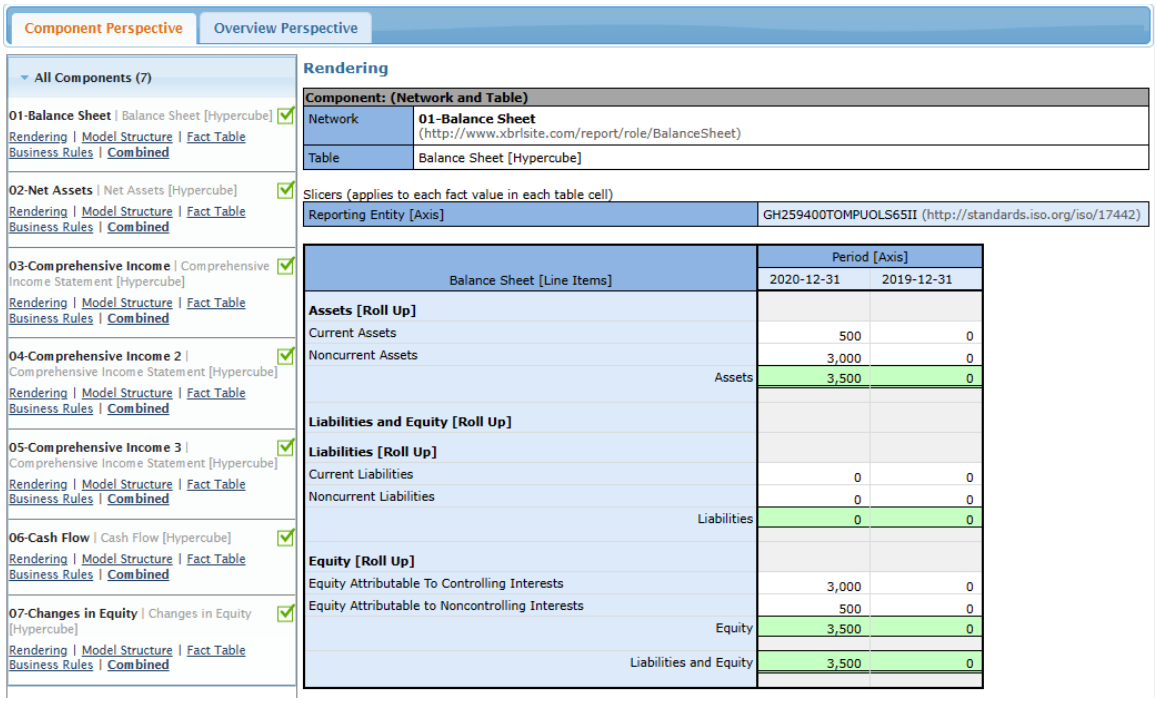
As explained in the document, *Financial Report Knowledge Graph*[436]; here is a "specialized" or specific view of one type of knowledge graph, a financial report, that is specific to the area of knowledge of financial reporting:



Here is an example of an XBRL-based digital financial report that has been converted into an HTML human readable rendering of that machine readable knowledge graph[437]:

[436] Charles Hoffman, CPA, *Financial Report Knowledge Graph*, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf

[437] *HTML rendering of financial report knowledge graph*, http://www.xbrlsite.com/seattlemethod/golden/common2/reference-implementation/evidence-package/



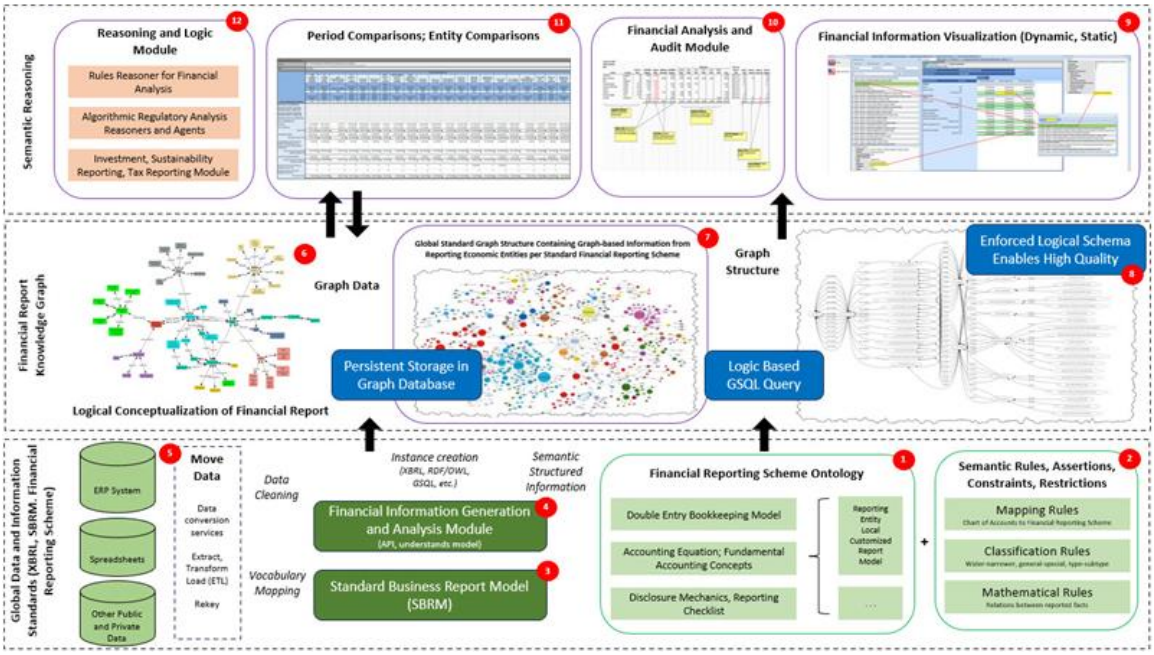
8.13. Knowledge Graph Systems for Financial Reporting

Think of applying the notion of a knowledge graph system to financial reporting. The graphic that I show below is my view of how a knowledge graph system for financial reporting might work and more importantly why I think it will work that way.

First, you have to understand that a financial report is, and always has been, a knowledge graph[438]. In the past, that financial report knowledge graph was only readable by humans. Going forward, that financial report knowledge graph will be still be readable by humans; but it will also be readable by a machine in the form of a software application.

This transformation is less about artificial intelligence (AI); it is more about a transformation caused by HUMANS effectively harnessing the power of AI[439]. Transformation = AI + HI. The transformation will be a lot of work, most people will get it wrong, but a few will get it right and then everyone will copy those who got it right and then improve things even more. Where things end up will be a system similar to the graphic below. Here is a graphic that describes my view of the pieces that make up a knowledge graph system for financial reporting[440]:

[438] *Financial Report Knowledge Graph*, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf
[439] *Transformation = AI + HI*, https://digitalfinancialreporting.blogspot.com/2023/04/ai-hi.html
[440] *Knowledge Graph System for Financial Reporting* (Graphic), http://xbrlsite.com/seattlemethod/platinum/KnowledgeGraphSystem_FinancialReporting.jpg



For more details and examples of the pieces of that system, refer to this blog post[441]. So how do you physically represent that knowledge graph system? Well, you use a knowledge assembly.

8.14. Global Standard Knowledge Assembly

Imagine a global standard knowledge assembly for financial reporting.

I provide examples of what amount to a knowledge assembly in my examples of different general purpose financial report creation schemes[442]. All of my examples use the same framework which I refer to as the Seattle Method. That framework is heavily tested and is proven to work effectively[443].

My framework uses the global standard XBRL to represent the knowledge graphs within a standards-based knowledge graph system using a standards-based framework (Seattle Method, Standard Business Report Model) that make up the knowledge assembly. Other machine readable representation approaches of such a knowledge assembly exist such as the Semantic Web Stack (RDF+OWL+SHACL and then use SPARQL to query information) or a graph database (using GSQL[444]) or PROLOG (modern ISO standard PROLOG[445]) or other such similar robust standards-based mechanisms.

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[441] *Knowledge Graph System for Financial Reporting*, https://digitalfinancialreporting.blogspot.com/2023/07/knowledge-graph-system-for-financial.html

[442] General Purpose Financial Reporting, https://digitalfinancialreporting.blogspot.com/2023/02/general-purpose-financial-reporting.html

[443] XBRL + SBRM = Improved BI, https://digitalfinancialreporting.blogspot.com/2023/08/xbrlsbrm-improved-bi.html

[444] Graph Query Language, https://en.wikipedia.org/wiki/Graph_Query_Language

[445] Modern Prolog, https://digitalfinancialreporting.blogspot.com/2023/05/modern-prolog.html

A knowledge assembly is a set of knowledge graphs. A knowledge graph is a machine-readable structured representation of knowledge (semantics) related to a particular area of interest. So a knowledge assembly is a machine-readable network[446] of things and relations between things. The things and relations are classified or grouped in helpful/useful ways. Semantics is the science of giving meaning to data. Knowledge assemblies are about semantics which is data in context, a.k.a. information. Knowledge = ontology (things and relations between things) + rules (assertions, restrictions, constraints). A knowledge assembly can be explained using a logical theory or logical schema that verifies/validates the knowledge assembly. Knowledge assembly terminology is grounded in the more approachable and innately understandable terminology of logic and philosophy[447], not the technical jargon/terminology of computer science.

What always seems to be necessary to work with some machine-readable knowledge assembly is:

1. Some sort of database to store the knowledge within.
2. A logical model that is used to understand and process the information within that knowledge assembly.
3. Some sort of reasoning engine or semantic reasoner or rules engine that understands the logical model (#2) and processes the information in the database (#1) to give you the answers that you need from the knowledge stored in the knowledge assembly.

This capability, when implemented effectively, is an incredibly useful tool. This can be a general tool, think semantic spreadsheet or a specific tool for financial reporting. But you need to make it work like a well-oiled machine for the capability to be useful.

8.15. Knowledge Portal (Accounting Oracle Machine)

An oracle is a person or agency, like a software application, considered to provide wise, insightful, useful information or counsel or perhaps useful simulations or predictions. For example, a Certified Public Accountant (CPA) provides accounting and business related advice on specific topics; a CPA is an example of an oracle: a trusted business adviser.

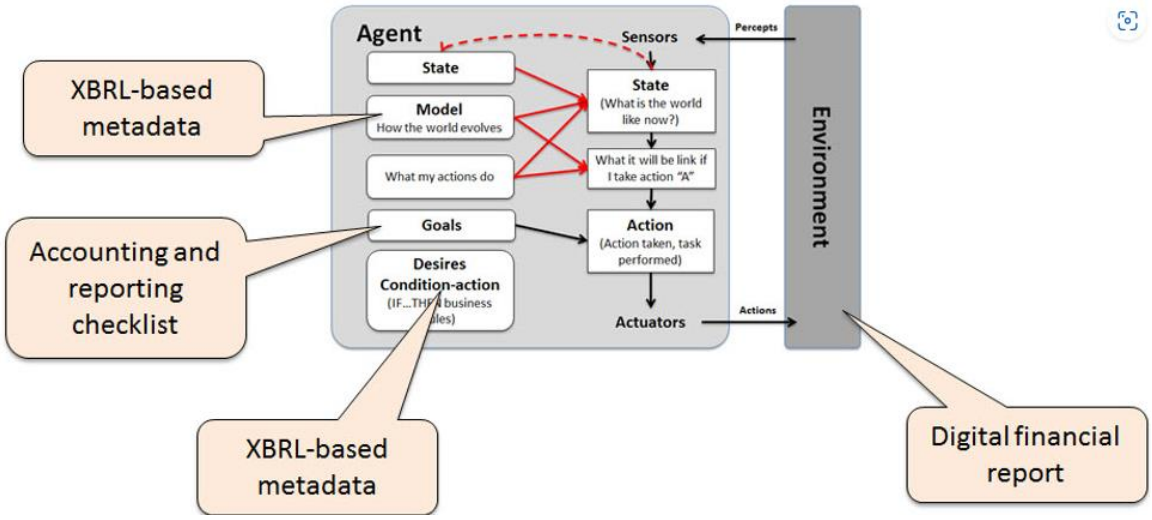
An oracle machine can be thought of as a Turing machine connected to an oracle of machine-readable information and rules. The oracle, in this context, is a software application capable of solving some computational problem (logical, mathematical), which for example may be a construction problem, a decision problem, or a function problem. Think rules-based expert system for very precise and accurate information and counsel or maybe a ChatGPT "copilot" type thingy that is more probability based, but helpful.

If you don't understand rules-based expert systems or intelligent agents; it is really time to learn. There is ZERO PROBABILITY that artificial intelligence will have no

[446] Wikipedia, Network, https://en.wikipedia.org/wiki/Network_theory
[447] Simple Explanation of a Logica System, https://digitalfinancialreporting.blogspot.com/2023/06/simple-explanation-of-logical-systems.html

impact on accounting, reporting, auditing, and analysis. Exactly WHAT impact is still to be determined, but trust me; the impact will not be "nothing".

Here is a diagram that explains what an intelligent software agent might look like and do: (to understand more details, read the information provided above)



8.16. Knowledge Hive (Semantic Hive or Hive Plot)

A sematic hive or hive plot[448] is is a group that has a similar view and have similar "ontological commitment" or "knowledge commitment". Effectively, each "semantic hive" or "hive plot" is mutually exclusive: you belong to one semantic hive or another semantic hive, you cannot belong to both because that would be illogical.

Here is an example. Say you wanted to create a knowledge graph of the semantics of the U.S. Constitution. If you tried to get everyone to agree with one single knowledge graph, this could be quite a challenge. But, if you broke up the group of people trying to do this into "semantic hives" or "hive plots" such as "democrat" and "republican" and/or "conservative" and "liberal" figuring out what goes into that knowledge graph becomes significantly easier. Then, you could use the semantic hive or hive plot created by the group you subscribe to most to perform reasoning.

8.17. Semantic Web

Digital distributed ledgers, smart contracts, nonfungible tokens (NFTs), the Interplanetary File System (IPFS), decentralized autonomous organizations (DAOs), and other such technologies will be used to implement interesting new capabilities.

8.18. Knowledge Products

Now, think less of logical digital twins and try and think more about what you can do with a properly functioning logical digital twin. Knowledge products offer completely

[448] Semantic Hive or Hive Plot, https://digitalfinancialreporting.blogspot.com/2024/01/notion-of-semantic-hive-or-hive-plot.html

new business models[449]. Imagine represented your skills and abilities in machine-readable form so that a computer software application can perform work using your knowledge.

A **data product** is generally a reusable raw and unprocessed data asset, engineered to deliver a trusted dataset to a user for a specific purpose. It integrates data from relevant source systems, processes the data, ensures that it is compliant, and makes the data accessible to those with the right credentials. The focus of a data product is raw, unprocessed data which can be numbers, text, or some sort of measurement. Examples of a data product are stock market data, website traffic lots, social media posts. The data might be delivered in the form of a CSV file, spreadsheets, an API, an XML file, RDF, JSON.

An **information product** tends to provide processed information to the information product's user. Information products are often used to monetize knowledge. Information products are organized and interpreted data which provides context and meaning. Information is generally provided in a way that the information can be consumed such as reports, dashboards of information, articles, and in the future very likely machine-readable knowledge graphs of high-quality information.

A **knowledge product** is refined and actionable information that has been processed, organized, and/or structured in some way or put into practice in some way making the information super-useful. The information is ready to use. The knowledge is derived from expertise, research, lessons learned. Knowledge products allow the user of the knowledge product to make informed decisions or better decisions.

Knowledge products provide insights, best practices, good practices, expertise which was derived from information, skills and experience. Knowledge products tend to answer "why" and "how" types of questions. Knowledge products can be delivered in a wide variety of forms such as training material, templates, guides, checklists, tutorials, artificial intelligence models, spreadsheet models. In the future knowledge products will, I believe, include machine-readable knowledge graphs that, preferably, use a global standard format and are proven to be of high quality per a logical schema.

Knowledge products empower their users, and the user could be a human or a software application such as an expert system for creating financial reports or your tax return. AI-powered software agents or assistants need machine-readable knowledge to operate. Subject matter experts in some area of knowledge will create these knowledge products.

An example of a knowledge product is an accounting oracle machine which I have mentioned before here and here.

Knowledge products are actionable; they should equip the users of the knowledge product to make informed decisions or take effective action in the moment. This could be in the form of recommendations of some sort, knowledge about best practices, or maybe a checklist or step-by-step guide. Knowledge products are driven by the skills and expertise and deep understanding gained within some specific field. Knowledge products do not provide a surface level understanding, they offer true insights and understanding.

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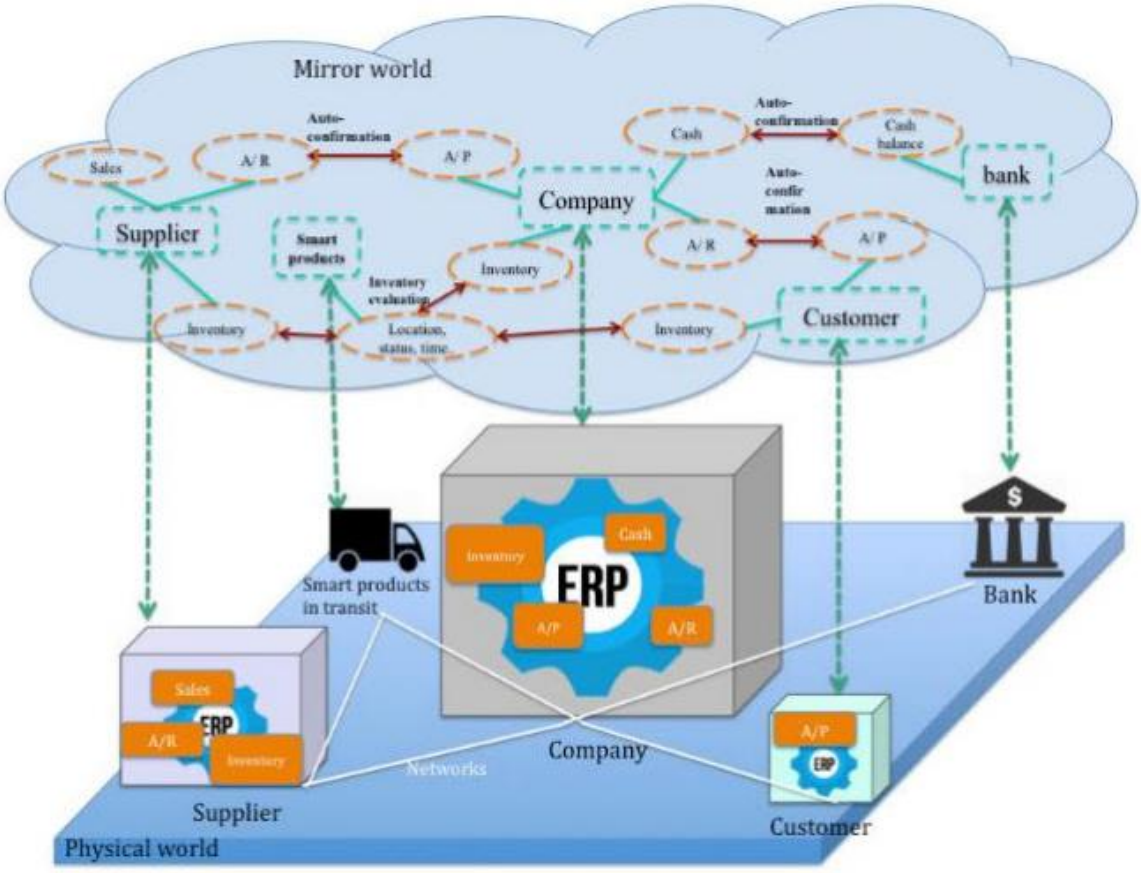
[449] *Knowledge Products offer New Business Models*, https://digitalfinancialreporting.blogspot.com/2024/02/a-new-business-model-is-emerging-which.html

Knowledge products tend to be tailored to the audience or a specific group of users and address the needs and challenges of that audience or group. Knowledge products might teach new knowledge. They might provide expert consultations to tap into the expertise of specific individuals or organizations. They could provide personalized recommendations or solutions to very specific problems.

8.19. Digital Twin for Financial Status and Performance of Economic Entity

Now, imagine a digital twin that is created using this global standard knowledge assembly[450].



8.20. Logical Digital Twin for Financial Reporting

And that leads us to the notion of a logical digital twin specifically designed for financial reporting. Such a logical digital twin is a knowledge graph of professional quality that is specific to an area of knowledge, financial reporting in our case, that has a logical schema that enforces the logic represented by the knowledge graph.

This logical digital twin might be represented in a number of different technical formats such as XBRL, RDF+OWL+SHACL, PROLOG, DATALOG, GSQL, SQL or some other technical format.

[450] Digital Twin for Financial Status and Performance of Economic Entity, https://digitalfinancialreporting.blogspot.com/2023/09/digital-twin-for-financial-status-and.html

Using a machine-understandable logical digital twins represented using a global standard technical syntax such as XBRL or RDF; it is possible to describe quantitative and qualitative associations between facts or sets/assemblies of facts within a report, such as a financial report or other type of business report. Such associations can have any degree of complexity. This information can then be reasoned on using a logic engine such as DATALOG which is an implementation of nearly a complete set of first order logic (i.e. some risky capabilities were removed in order to guarantee that catastrophic logical failures caused by logical paradoxes do not occur and therefore the processing is certain and reliable).

9. Testing (Properly Functioning Logical System)

An excellent way of making sure things are right is by studying what can go wrong. To understand what a properly functioning logical system looks like; study the common impediments to a properly functioning logical system.

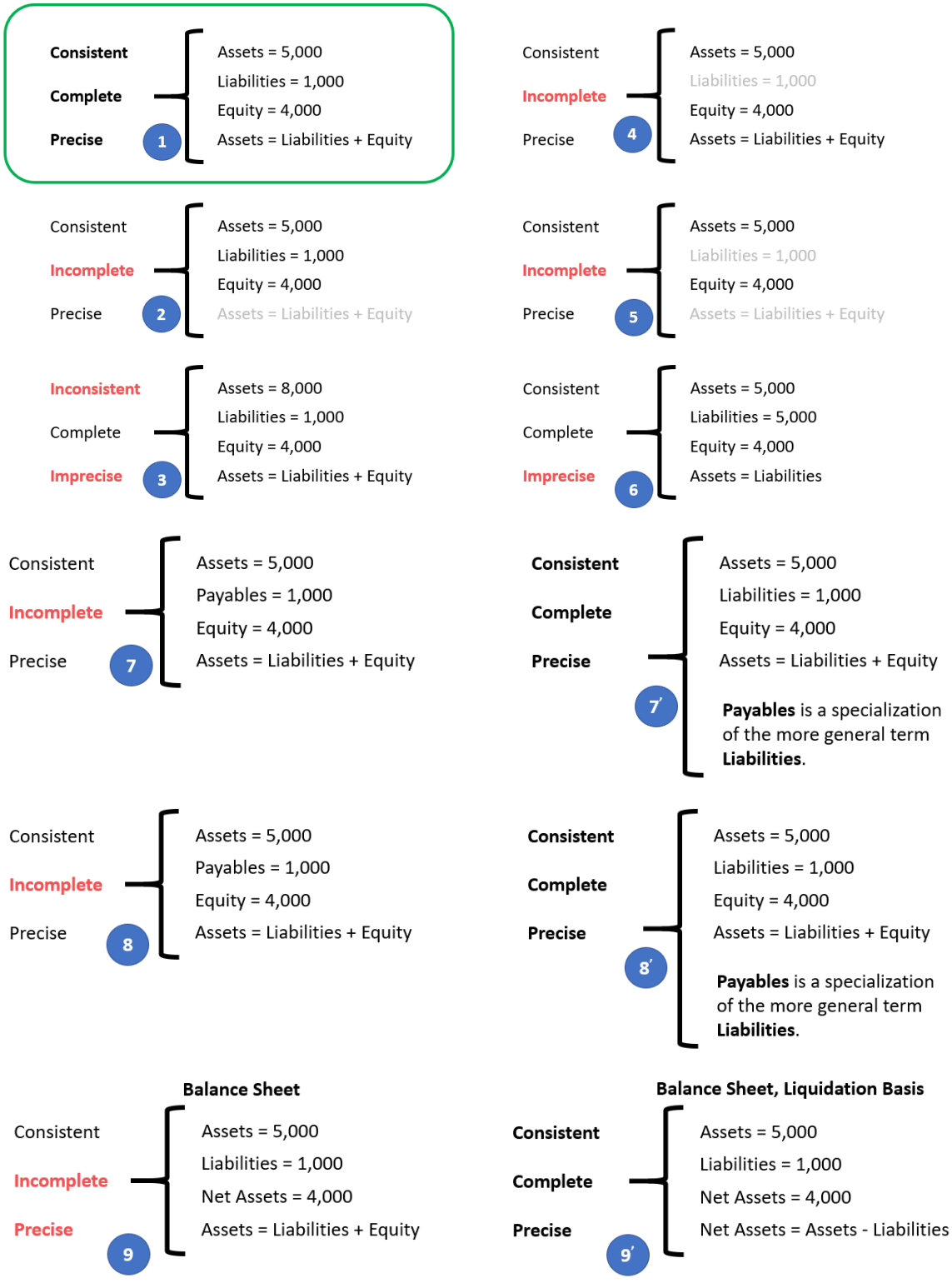
The following is a comparison of 9 states of the simple financial report logical system, the accounting equation[451]. The point of using such a simple financial report logical system is to explain specific things that can go wrong so that a reader can understand why each of the categories of rules are necessary to control a process to make sure things are in fact right. These 9 states can occur in any financial report with one fragment, two fragments, or 194 fragments like the Microsoft 10 K. Again, *Mastering XBRL-based Digital Financial Reports*[452] walks you through small and simple to large and complex. For more information about these impediments, please watch the video playlist Understanding the Financial Report Logical System[453], in particular the three videos related to impediments.

Here is a summary of all nine states with the first state outlined in green being the only properly functioning logical system proven to be complete, consistent, and precise:

[451] Accounting equation, http://xbrlsite.azurewebsites.net/2020/master/ae/index.html

[452] Mastering XBRL-based Digital Financial Reports, http://xbrlsite.azurewebsites.net/2020/master/

[453] Understanding the Financial Report Logical System, https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt



In the following sections I want to make some adjustments to the logical system which make the logical system either inconsistent, incomplete, or imprecise and explain why the system is then not a properly functioning logical system. I made

videos that explain each of these impediments to a properly functioning logical system which you can see in this video playlist, *Understanding the Financial Report Logical System*[454].

Before we get to the improperly functioning logical systems, let's take one final look at the properly functioning logical system so that you can use that as a baseline for comparing and contrasting the properly functioning and improperly functioning logical systems so that you can understand they sorts of errors that can occur.

SUMMARY:

- **State 1**: A report can be provably properly functioning per a set of rules. The State 1 report is an example of a properly functioning financial report. **All the logical statements are provided for per a set of machine-readable rules, the statements are consistent with one another, and the information is precise per the area of knowledge (in this case the accounting equation)**. The Pacioli logic engine verifies all this.
- **State 2**: If you REMOVE a logical statement, such as if you REMOVE the rule "Assets = Liabilities + Equity"; and three facts are reported; a machine-based process can have NO IDEA whether those three facts are CORRECT or INCORRECT using automated processes because the RULE IS MISSING. NO MACHINE-READABLE RULE, MACHINE CANNOT VERIFY.
- **State 3**: If you intentionally put information in the report to simulate an error; Pacioli DETECTS that error and a human can SEE that from the verification results. But for inconsistencies to be detected, the machine-readable rules must exist.
- **State 4**: If a line item is not reported, this causes increased complexity in processing reports. For example, if you leave out the line item "Liabilities" BUT you don't provide a machine-readable derivation rule, there is NO WAY a computer can UNDERSTAND THE information.
- **State 4'**: But as State 4' shows, if you DO provide the derivation rules, the system will still be able to automate effectively because the missing information can be derived. It just calls for additional work (i.e. creating the derivation rule BECAUSE not reporting certain line items is allowed). Don't what to cause additional work? Don't want to cause additional RISK of misunderstanding? Then DON'T ALLOW unreported high-level line items.
- **State 5**: If a line item is NOT reported AND the consistency rule is not provided; THEN there is no way a machine-based process can effectively use the report. Remember, computers are INCREDIBLY DUMB. They need to be led by the hand; that is what machine-readable rules do.
- **State 6**: It is possible to represent a report, get 100% of the verification checks to be GREEN; but the report is STILL WRONG. If (a) a FACT is wrong and (b) if a RULE is wrong; the two can work together to make a report seem CORRECT. However, this situation can be detected by using high-level crosschecks of the continuity of a report.

[454] Understanding the Financial Report Logical System, https://www.youtube.com/playlist?list=PLqMZRUzQ64B7EWamzDP-WaYbS_W0RL9nt

- **State 7**: If a report uses an extension concept to report a fact, the MACHINE will not understand how to process the extension information, so humans MUST step in to sort things out. As such, a process cannot be automated.
- **State 7'**: "Anchoring" helps OVERCOME State 7; the machine-readable anchoring information enables a process (a) to be automated and (b) the use of extensions to make the system more flexible which maximizes system "information richness".
- **State 8**: The EXACT SAME PROBLEM that anchoring solves with extension concepts exists with BASE TAXONOMY CONCEPTS!!! Again, computers are dumb, dumb, dumb. If anchoring is not also used in the base taxonomy, then you have EXACTLY the same problem you have with extensions.
- **State 9**: The EXACT SAME PROBLEM that anchoring solves exists with DISCLOSURES (i.e. SETS of concepts). Whether a disclosure (structure) is in a report model or base taxonomy model; if an automated process cannot sort out what that structure/disclosure is; then it WILL NOT KNOW WHAT TO DO WITH IT. Anchoring applies to structures/disclosures as it does to concepts, report or base models.
- **State 10**: The report models need to be represented logically. What does "indentation" of a concept mean? Whatever you thing it means, it means something else to someone else. Every Tom, Dick, and Harry has their own personal interpretation. Don't use "indentation" (parent-child associations) to carry ambiguous meaning. Remember, computers are REALLY dumb.
- **State 11**: Fundamentally, the "payload" of information must be provided by a standard technical syntax. It an improper XBRL technical syntax is used, software may not work correctly. XBRL technical syntax tends to be pretty good because XBRL International publishes a conformance suite which can be used to test software to see if the software is detecting mistakes correctly in XBRL technical syntax.

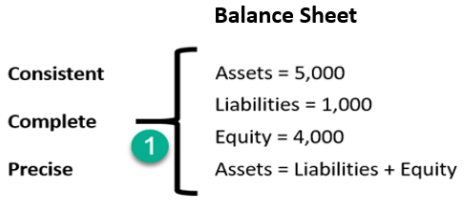
Next, we will elaborate on the details of each state a bit more.

9.1. State 1: Properly Functioning Logical System

For completeness, I want to start by mentioning again our properly functioning logical system which is consistent, complete, and precise. It can be helpful to contrast other states to this state to understand the difference between properly functioning logical systems and improperly functioning systems.

Balance Sheet [Abstract]	Period [Axis]
	2020-12-31
Balance Sheet [Abstract]	
Assets	5,000
Liabilities	1,000
Equity	4,000

Result	Rule
Pass	$Assets = $Liabilities + $Equity



Again, this is considered a properly functioning logical system because (a) all the statements within the system are **consistent**; (b) the set of statements that describe the system is **complete**; and (c) the information conveyed by the system is

precise in its representation of reality. Further, we are formally declaring this "reality"[455] to be our base understanding.

Also, we need to be explicit. We defined three terms "Assets", "Liabilities", and "Equity".

Now, you may know what those three terms are; but a computer does not. You have to define what you work with relative to something that you know. Imagine our system defines four terms, "fac:Assets", "fac:Liabilities", "fac:Equity", and "fac:LiabilitiesAndEquity"[456]. You understand your system but you have to map every external system into your system[457]. Your internal system understands more that the accounting equation system (i.e. you have LiabilitiesAndEquity). You have to be able to compute that value based on some other system's information[458]. It is perfectly reasonable for our system to create a concept LiabilitiesAndEquity and compute that value even though the accounting equation logical system does not have that explicit value.

The point is that different economic entities have different models; but all models of a financial reporting scheme are reconcilable from/to one another in some manner[459].

9.2. State 2: Incomplete Coverage by Rules

The logical system #2 below is intended to show exactly the same information as our #1 properly functioning logical system, except that #2 leaves out the rule "Assets = Liabilities and Equity" which is showed as grayed out (i.e. because it is assumed to be missing from the logical system.

Coverage is a measure of how well you do or can represent a domain of information within a logical system. "Do" is about using the tools you have correctly and effectively. "Can" is about the capabilities of the tools you are using to represent the rule.

For example, if your logical system neglects to include the rule "Assets = Liabilities + Equity" or if your tools don't provide the capabilities to allow you to represent that rule; then there is the possibility that the facts being represented to be represented incorrectly and the system will not detect the inconsistency. As such, that logical system has **incomplete coverage**.

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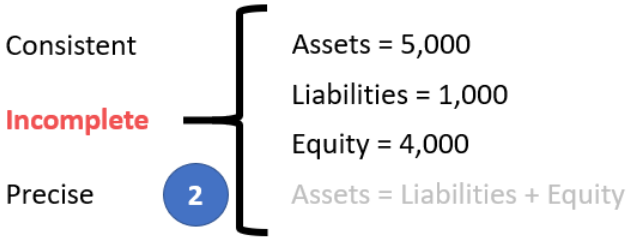
[455] YouTube, *Reality*, https://youtu.be/eq2Jw6waaCI

[456] Fundamental accounting concepts, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac.xsd

[457] Mapping from accounting equation to fundamental accounting concepts in our system, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml

[458] XBRL Formula to derive the value for LiabilitiesAndEquity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-ImputeRule-LiabilitiesAndEquity-formula.xml

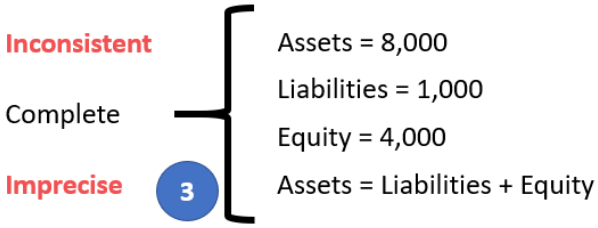
[459] Charles Hoffman, CPA, *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*, http://xbrl.squarespace.com/journal/2019/12/30/special-theory-of-machine-based-automated-communication-of-s.html



While this specific state #2 does have the Assets, Liabilities, and Equity facts consistent with the absent rule; the system is still incomplete because the coverage can be improved by adding the missing rule. If that missing rule is added, then the logical system can be considered complete again.

9.3. State 3: Inconsistent and Imprecise

All the statements in the system must be consistent for the logical system to be considered properly functioning. If statements are inconsistent, the logical system is not is not properly functioning. In this system #3, the values for Assets, Liabilities, and Equity are inconsistent with the rule "Assets = Liabilities + Equity". From looking at the information provided, it is impossible to know exactly which of the three facts are incorrect; it is only possible to understand that the statements made within the logical system is inconsistent. It could be the case that the rule is incorrect.



However, given that we know from state #1 that the value for Assets is 5,000 and not 8,000; the facts in this system is imprecise because the fact for Assets does not reflect reality.

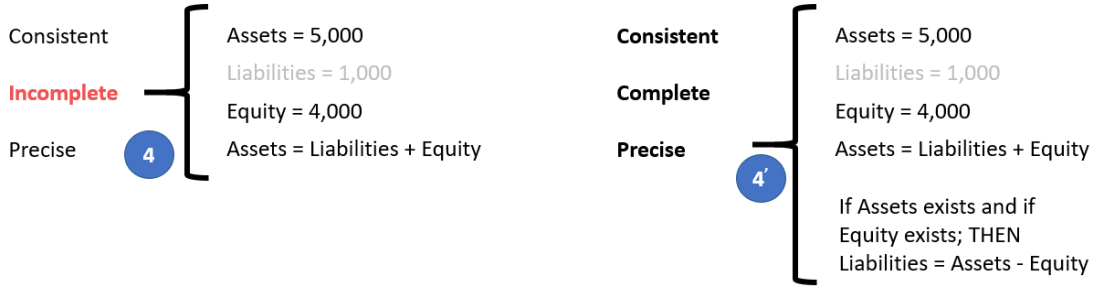
9.4. State 4: Unreported Facts

In state #4, the situation is that the economic entity representing information in their report neglected to include the fact for Liabilities. Whether it is the case that a fact can, or cannot, be left unreported is a decision that can be made by the stakeholders of the system.

If it is the case that it is decided that the fact "Liabilities" can be omitted if both Assets and Equity are reported; then you must provide a rule to derive the value of Liabilities when that fact is not reported. Below you see that the system has been adjusted in state #4' to add the rule "IF Assets exists and if Equity exists; THEN Liabilities = Assets - Equity"[460]. *(NOTE that this rule should actually be "IF Assets*

[460] Here is the impute or derivation rule that would be added to the accounting equation logical system for this situation, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-1-Code-BS-Impute-01-formula.xml

exists and if Equity exists and if not(exists) Liabilities; THEN Liabilities = Assets – Equity")



If it were likewise true that either Assets[461] or Equity[462] could also be left unreported, similarly derivation rules could be created for each of those facts. Note that XBRL Formula chaining[463] can be used to physically derive unreported facts if any one of these three facts remain unreported. Note that it is impossible to derive missing information if any two of the facts remain unreported. Adding the derivation rule makes the system complete.

Allowing certain line items of a report to go unreported specifies the need to create rules to derive missing information. Or saying this another way, omitting the possibility of unreported facts negates the need for creating derivation rules.

A second downside of allowing unreported facts is that you lose the parity check or cross check if facts can go unreported. Said another way, it would be considered best practice to not leave important high-level financial report line items to go unreported.

9.5. State 5: Incomplete

Similar to state #4, in state #5 the logical system is incomplete because both (a) the fact Liabilities is unreported and also (b) the consistency rule "Assets = Liabilities + Equity" is missing from the logical system. Because both a fact and the rule are missing from the logical system, it would be impossible to deduce the value of Liabilities in this case. There is not enough information in the logical system to allow Liabilities to be derived. At a minimum, a consistency crosscheck rule[464] plus the derivation rule to impute Liabilities[465] would be necessary.

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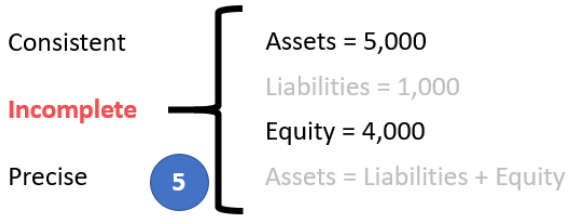
[461] XBRL Formula rule for deriving Assets, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-3-Code-BS-Impute-03-formula.xml
[462] XBRL Formula rule for deriving Equity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-2-Code-BS-Impute-02-formula.xml
[463] Deriving Facts Using XBRL Formula Chaining (Example), http://xbrl.squarespace.com/journal/2019/4/24/deriving-information-using-xbrl-formula-chaining-example.html
[464] XBRL Formula consistency crosscheck rule Assets = Liabilities + Equity, http://xbrlsite.azurewebsites.net/2020/core/master-ae/Consistency-5-Code-BS01-formula.xml
[465] XBRL Formula derivation rule to impute Liabilities, http://xbrlsite.azurewebsites.net/2020/core/master-ae/ImputeRule-Key-1-Code-BS-Impute-01-formula.xml

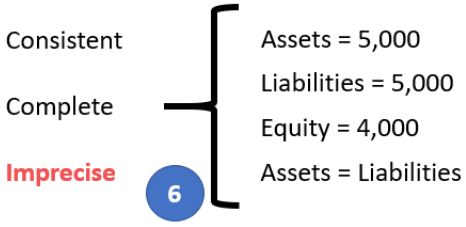


Again, consistent with state #4; Assets and Equity would require similar rules and there is no parity check of reported information.

9.6. State 6: Imprecise

A logical system is a true and fair representation of some agreed upon realism. **Precision** is a measure of how precisely you do or can represent the information of a domain within a logical theory. The reality that we formalized in state #1 indicates that "Assets = Liabilities + Equity". Yet, in the state #6 example, the rule "Assets = Liabilities" was provided. Further, the values of Assets and Liabilities are, in fact, consistent with the rule that has been provided.

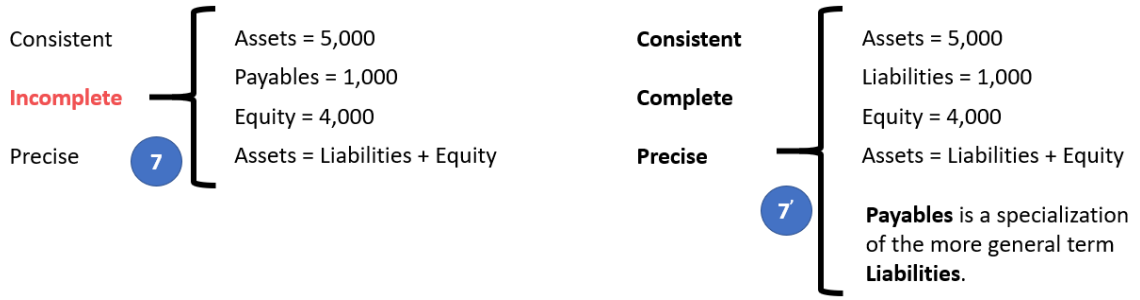
Remember that in state #1 we formalized our truth to be that "Assets = Liabilities + Equity". As such, this logical system can be described as being imprecise. To make this logical system precise, all that needs to be done is to fix the rule.



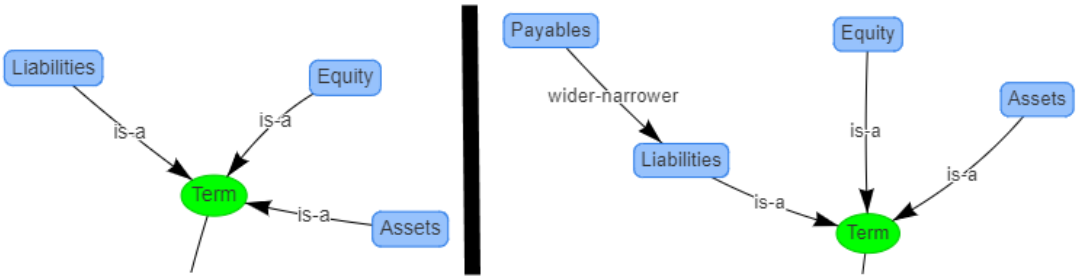
9.7. State 7: Extension Concept

In state #7 on the left, what we are trying to convey is that the economic entity reported the fact for Liabilities using the extension concept "Payables" that it had created. If a fact is represented using an extension concept created by a reporting entity; then a "general-special" or "wider-narrower" or "class-equivalentClass" association must be created to indicate to software applications of the relationship so that information can be used correctly. State #7' on the right, the rule "Payables is a specialization of the more general term Liabilities" has been added to the logical system which allows the system to operate effectively[466].

[466] XBRL Definition relations showing example of a mapping rule, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml



And so, the graphic below shows a fragment of the knowledge graph on page 9 above before and after the information that "Payables is a specialization of the more general term Liabilities," was added. On the left you see State 7, the taxonomy before the information was added and on the right you see "Payable" being added as an extension concept indicating that there is a "wider-narrower" relationship between Payables and Liabilities. Therefore, a machine based process can utilize the information per State 7' because the process understands Liabilities in the taxonomy, understands the "wider-narrower" relationship therefore knowing that "Payables" is a type of Liability.



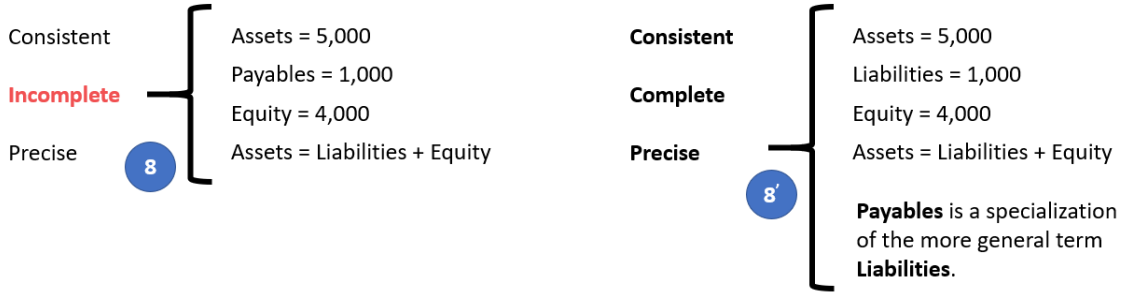
9.8. State 8: Base Taxonomy Wider/Narrower Concept Use

State #8 on the left below is similar to state #7 in that a different concept is used to report a fact; but while state #7 focuses on using an extension concept; state #8 points out that using a wider or narrower base taxonomy concept gives exactly the same result.

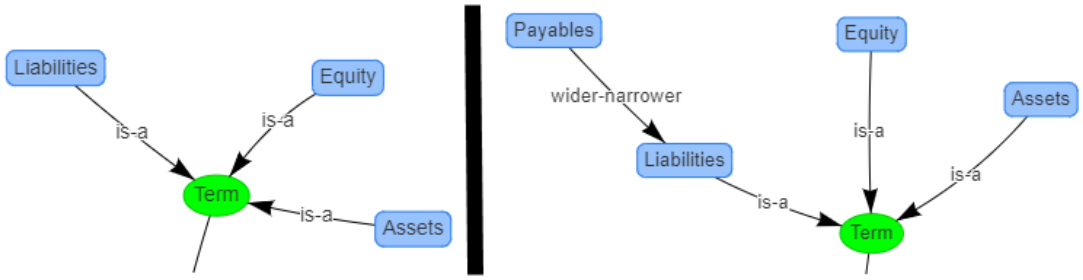
Now, our base state #1 does not have the concept "Payables"; but let's assume for a moment that it does have the concept "Payables". Also suppose that there was no information in the base logical system indicating the relationship between "Payables" and any other concept. If a fact is represented using a BASE TAXONOMY CONCEPT by a reporting entity; then a "general-special" or "wider-narrower" or "class-equivalentClass" association must exist in that base taxonomy to indicate that some concept is a permissible alternative for some other concept.

State #8' on the right adds the rule "Payables is a specialization of the more general term Liabilities"[467].

[467] XBRL Definition relations showing example of a mapping rule, http://xbrlsite.azurewebsites.net/2020/core/master-ae/fac-mapping-definition.xml



And so, the graphic below shows a fragment of the knowledge graph on page 9 above before and after the information that "Payables is a specialization of the more general term Liabilities," was added. On the left you see State 8, the base taxonomy before the information was added and on the right you see "Payable" being added as an extension concept indicating that there is a "wider-narrower" relationship between Payables and Liabilities. Therefore, a machine based process can utilize the information per State 8′ because the process understands Liabilities in the base taxonomy, understands the "wider-narrower" relationship therefore knowing that "Payables" is a type of Liability.

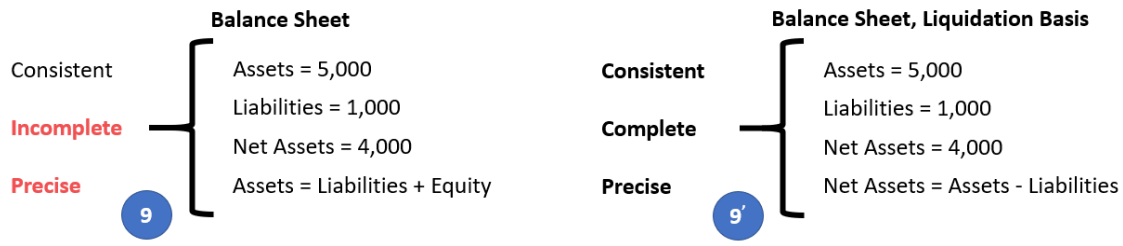


9.9. State 9: Defining a Completely New Structure

State #9 below on the left focuses on the structure as contrast all the prior examples which focused on the terms and rules. If a new structure is created, the new structure must be referenced to the base taxonomy and the new structure needs to be explained using machine-readable rules[468]. Even base taxonomy structures need to be defined in order to be referred to[469]. When you say "Balance Sheet" you know what that means. But a machine does not know.

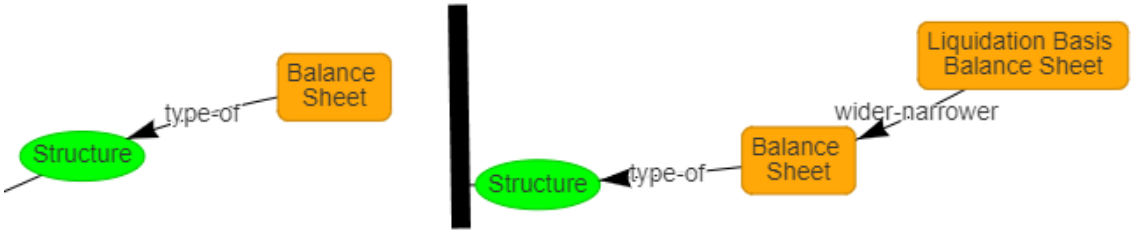
A base taxonomy should (a) provide all necessary structures separately, not intermingle different models in the same set of associations and (b) define what each structure must look like. Remember, computers are like babies and need to be led by the hand in order to understand the details you need them to understand.

[468] XBRL Definition relations used to represent structure rules, http://xbrlsite.azurewebsites.net/2020/core/master-ae/dm-1355-rules-def.xml
[469] XBRL taxonomy schema used to define "Balance Sheet", http://xbrlsite.azurewebsites.net/2020/core/master-ae/disclosures.xsd



Finally, in our case we have only one disclosure, the Balance Sheet. In our case, the Balance Sheet is always required to be reported per this logical system. As such, that rule is stated in a machine-readable reporting checklist[470]. Other logical systems with more disclosures will have more rules relating to when a disclosure is required to be provided in a report.

Similar to how "Payables" was added as an extension of the terms in the logical system; we can extend the structures to include a "Liquidation Basis Balance Sheet" structure which is a specialization of a Balance Sheet:



And such, an automated process will be able to understand the new structure because it is related to an existing structure. Other structures could be added and only identified as a type of structure.

10. The Great Transmutation to Digital

We are arguably in the midst of ***The Great Transmutation*** that is changing the world of financial accounting, reporting, auditing, and analysis (a.k.a. accountancy) in profound, fundamental and very likely in mostly positive ways.

Transmutation is defined as "the action of changing or the state of being changed into another form[471]". Another definition of transmutation is "an act that changes the form or character or substance of something[472]".

It is not like accounting has not changed or been changed before. Accounting has changed before in many ways[473]. Jane Gleeson-White titled chapter 1 of her book, *Double Entry: How the Merchants of Venice Created Modern Finance*[474];

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[470] XBRL Definition relations used to represent a reporting checklist or disclosure rules, http://xbrlsite.azurewebsites.net/2020/core/master-ae/reporting-checklist-rules-def.xml
[471] Google, *Transmutation*, https://www.google.com/search?q=transmutation+definition&oq=transmutation
[472] Vocabulary.com, *Transmutation*, https://www.vocabulary.com/dictionary/transmutation
[473] Accounting Timeline, http://xbrlsite.azurewebsites.net/2021/library/AccountingTimeline.jpg
[474] Amazon.com, Jane Gleeson-White, *Double Entry: How the Merchants of Venice Created Modern Finance*, page 10, https://www.amazon.com/gp/product/B007Q6XKA8/

Accounting: Our First Communications Technology. Accounting is fundamentally about communicating information.

Technologies improve over time. Accounting has been improved many times and in many ways during its long 7,000 year history.

Accounting started off being single entry, evolved to double-entry, and perhaps might evolve again to be triple-entry. There was a time when there was no notion of zero in accounting. In Europe, there was a time when accounting was performed using Roman numerals, now globally we use Hindu-Arabic numerals. The medium of accounting has change from physical tokens, to clay tablets, to papyrus, to bamboo stalks, to parchment, to paper, to e-paper, to digital knowledge graphs; and we might be moving back to tokens again, but this time those tokens could be digital.

Accounting and financial reporting is a **universal technology of accountability**[475]. This universal technology of accountability is grounded, even ingrained, in medieval traditions. Yet this universal technology of accountability is going to be impacted by structured information, artificial intelligence, digital distributed ledgers, and other such technologies. And they should be. Those same technologies that are causing the ever-increasing volume and complexity of information that is overwhelming us is also the solution to the information overload that is being experienced.

10.1. Part of Bigger Global Trends

The Great Transmutation of financial accounting, reporting, auditing, and analysis is part of a bigger trend, *The Great Upheaval*. Authors Arthur Levine and Scott van Pelt explain this change in their book by the same name[476].

Levine and van Pelt point out that we are in a time of profound, unrelenting, and accelerating change of a magnitude and scope unequaled since the Industrial Revolution. The United States is hurling from a national, analog, industrial economy to a global, digital, knowledge economy. So is the rest of the world. *The Great Upheaval* is part of an even bigger trend, *The Great Progression*[477].

> "The next 25 years will see the introduction and scaling up of not one but **three fundamentally new technologies** that will have world-historic impact. We're heading into a triple-whammy tech boom — not just another Long Boom, but a Long Boom Squared."

The Great Progression anticipates that the next 25 years will see the introduction of **three fundamentally new technologies** that will have a historic impact on the entire world, including the world of financial accounting, reporting, auditing, and analysis. Those three technologies are:

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[475] *Universal Technology of Accountability*, https://digitalfinancialreporting.blogspot.com/2023/02/universal-technology-for-accountability.html

[476] Google Books, Arthur Levine and Scott van Pelt, *The Great Upheaval*, https://www.google.com/books/edition/The_Great_Upheaval/Y5U9EAAAQBAJ

[477] Bigthink, Peter Leyden, *The Great Progression 2025 - 2050*, https://bigthink.com/progress/the-great-progression-peter-leyden/

- A clean energy system.
- The Biotech age and synthetic biology.
- Information technology stage two driven by artificial intelligence, structured information, and blockchain.

While financial accounting will likely not be impacted much or at all by the first two new technologies, the third will have a profound impact.

Another term for this trend is Industry 4.0 or the Fourth Industrial Revolution[478].

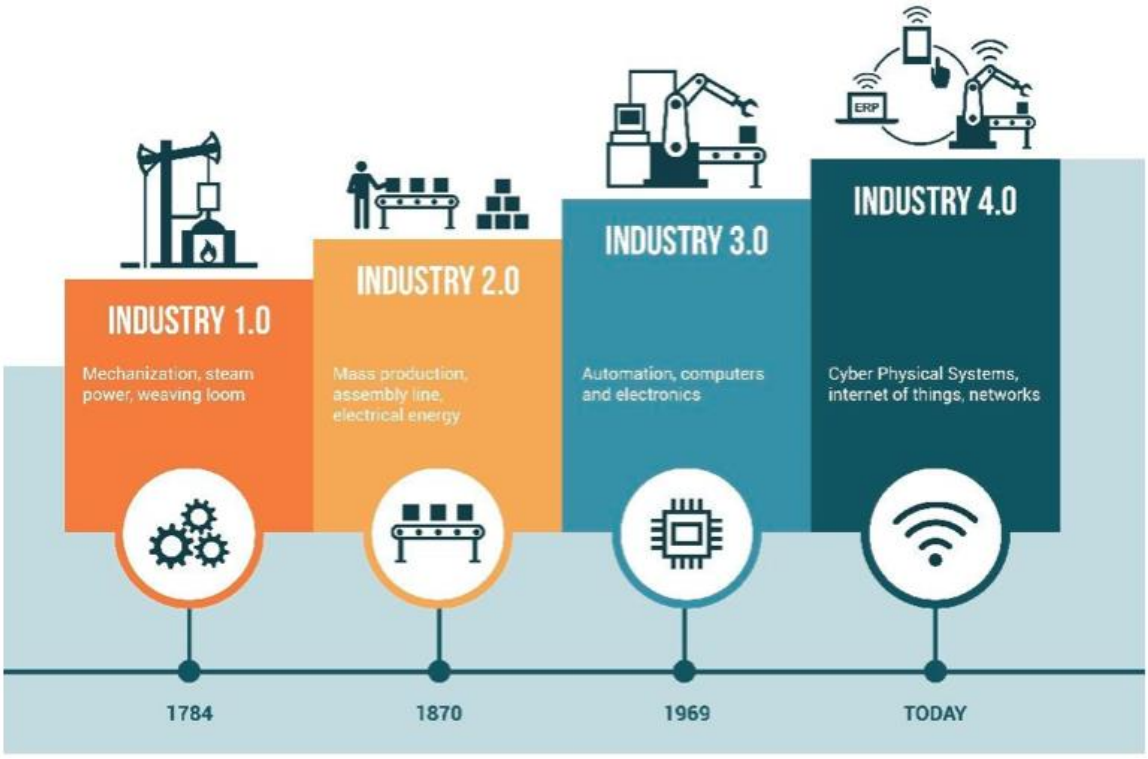
This great transmutation of accounting will be built on the foundation of a technology first developed by Italian banks, the global standard double-entry bookkeeping model which was created to detect errors and distinguish errors from fraud.

The result will be, or could be, I believe, a ***Universal Digital Financial Reporting Framework***[479] which will be an overhaul or complete rethinking of the paper-based accounting and reporting process that was then computerized during the first infotech revolution between the 1950s and now. Accounting will work in potentially completely new ways. Let me explain.

10.2. Environment

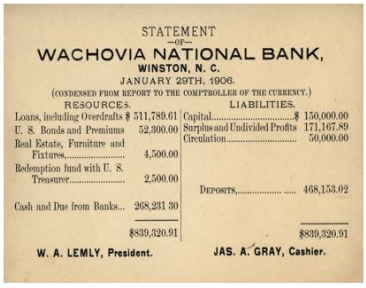
We are changing from an industrial economy to an information economy. Some call this an "algorithmic economy"[480]. This change offers unprecedented opportunities for interacting with customers in completely new ways and new business models that were never possible before. Changes like this, paradigm shifts really, are not new; we have seen them before. In our era we are changing from Industry 3.0 to Industry 4.0.

[478] Wikipedia, *Fourth Industrial Revolution*, https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution
[479] *Universal Digital Financial Reporting Framework*, http://accounting.auditchain.finance/library/UniversalDigitalFinancialReportingFramework.pdf
[480] The Business of Algorithms: Unveiling Its Global Economic Impact, https://www.linkedin.com/pulse/business-algorithms-unveiling-its-global-economic-impact-ko%C3%AFvogui/



The environment in which we will operate has changed. The three primary foundational changes are:

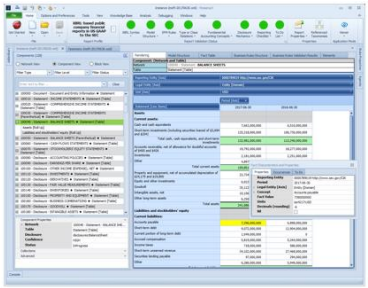
- structured machine-readable information in the form of knowledge graphs,
- artificial intelligence (deductive reasoning, inductive reasoning, abductive reasoning),
- publicly available and private digital distributed ledgers.



STATEMENT
—OF—
WACHOVIA NATIONAL BANK,
WINSTON, N. C.
JANUARY 29TH, 1906.
(CONDENSED FROM REPORT TO THE COMPTROLLER OF THE CURRENCY.)

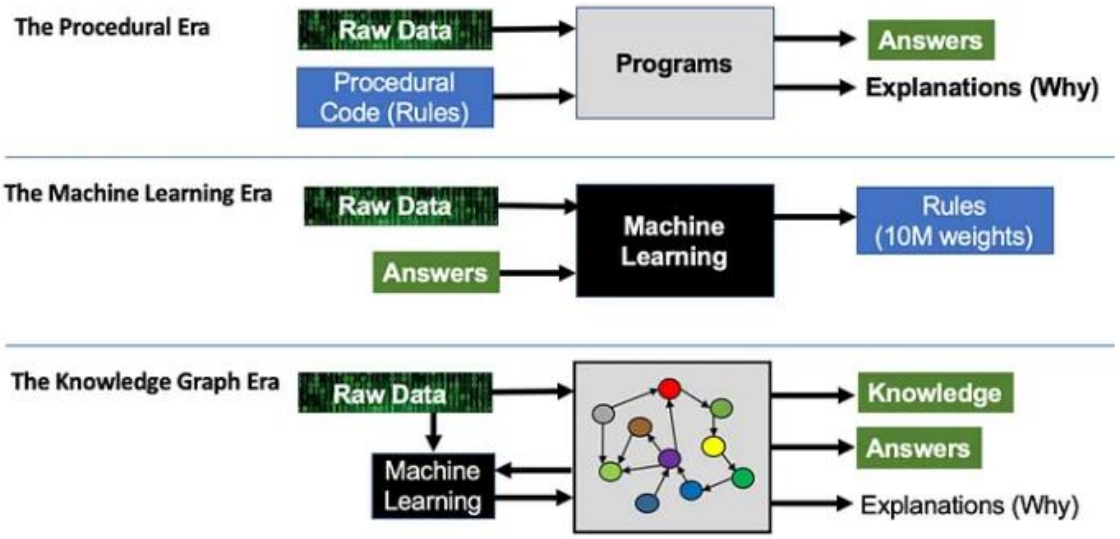
RESOURCES.		LIABILITIES.	
Loans, including Overdrafts	$ 511,789.61	Capital	$ 150,000.00
U. S. Bonds and Premiums	52,300.00	Surplus and Undivided Profits	171,167.89
Real Estate, Furniture and Fixtures	4,500.00	Circulation	50,000.00
Redemption fund with U. S. Treasurer	2,500.00	Deposits	468,153.02
Cash and Due from Banks	268,231 30		
	$839,320.91		$839,320.91

W. A. LEMLY, President. JAS. A. GRAY, Cashier.



As explained in the article, *Knowledge Graphs: The Third Era of Computing*[481], the era of the knowledge graph. This change from the procedural programming era to the era of knowledge graphs will have profound implications on how software is created and what software can be made to do.

[481] Dan McCreary, *Knowledge Graphs: The Third Era of Computing*, https://dmccreary.medium.com/knowledge-graphs-the-third-era-of-computing-a8106f343450



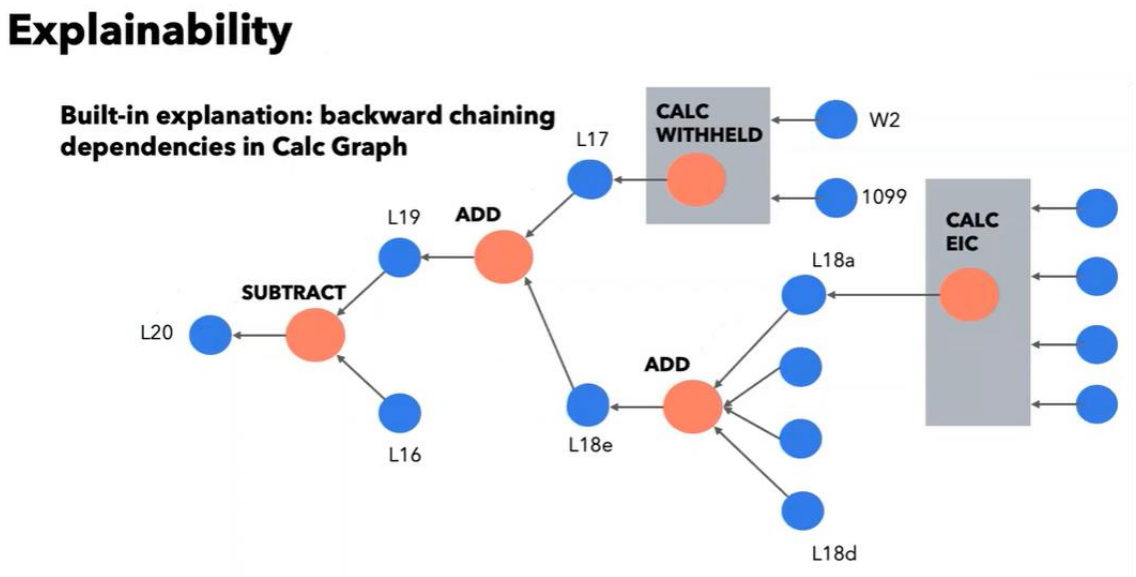
This change will move the logic followed by computer software from the software code written by software developers in the form of mainly "IF…THEN" statements effectively into what amounts to declarative rules[482] that are separated from software code and easier for business professionals to create and maintain.

	PROCEDURAL	KNOWLEDGE GRAPH
Logic	Procedural	Declarative
Execution	Sequential	Dependency-driven
Modularity	By best practice	By design
Explainability	Blackbox	Built-in
Personalization	Hard-coded, limited	Dynamic, automatic
Automation	Not manageable	Manageable
Testability	Harder	Easier
Optimized for	Exceptional complex logic	Most tax logic
Target Developer	Engineers	Domain experts

Knowledge represented in the form of natural language such as the pages in a book or a set of instructions can be hard to detect by humans. Providing this same information in the form of a diagram of this knowledge using simple graphics such as circles and lines can help the knowledge stand out. Further, these knowledge graphs tend to not only be better understandable by humans; the knowledge can also be understandable to computers. If a complete set of knowledge provided in this

[482] Business Rules Group, *The Business Rules Manifesto*, https://www.businessrulesgroup.org/brmanifesto.htm

manner and readable by computer processes, computers can be leveraged to check other information to see if that information is consistent with a provided set of knowledge, a.k.a. automated computer-based verification.



Finally, a new way of processing knowledge is possible when the actual knowledge is separated from the programming code, and "engine" or "rules processing engine" or "logic processing engine" can be created rather than computer programmers writing countless "IF…THEN" statements. Other benefits are opened up as will be explained.

10.3. Computational Professional Services

I refer to all this as *Computational Professional Services*[483]. (There might be a better term, but that is the term I am currently using).

Imagine a set of high-quality knowledge graphs organized into the form of a knowledge portal[484]. Imagine that the knowledge portal is enhanced by blockchain technology. Imagine that the knowledge graphs physical syntax is based on global standards and that the information within those knowledge graphs is also based on standards.

Imagine a system that is simple and elegant to use, rather than a poorly thought-out kludge.

Trying to understand what is going on by trying to plug the changes that you see into the current paradigm of accounting, reporting, auditing, and analysis is like walking around the city of Chicago with a map of New York City to try and find your way. Using the appropriate map would work better. This document helps you update your mental map.

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[483] *Computational Professional Services*, http://www.xbrlsite.com/mastering/Part00_Chapter01.A1_ComputationalProfessionalServices.pdf

[484] Data Science Central, Kurt Cagle, *From Knowledge Graphs To Knowledge Portals*, https://www.datasciencecentral.com/from-knowledge-graphs-to-knowledge-portals/

10.4. Standard Bookkeeping Mathematical Model

This transmutation has been unfolding since about 525 years ago in 1494 with the formalization, documentation, and standardization of double entry bookkeeping by Luca Pacioli.

The documentation of what is now referred to as the Venetian Method of double entry accounting and a standardization of the mathematical model of double entry bookkeeping[485] paved the way for one standard model that underlies accounting globally today.

That rich fundamental standard double entry bookkeeping mathematical model is the "keystone" or "cornerstone" of financial accounting and financial reporting.

10.5. Standard Accounting Metadata

This transmutation continued throughout the 20th Century. Another big step in the transmutation took place in the 1930's in the United States when the U.S. Securities and Exchange Commission (SEC) began standardizing the jargon of accounting and reporting into what has become United States Generally Accepted Accounting Principles[486] (US GAAP) in Regulation S-X[487].

Another big step in the transmutation was in 1975 when what became International Financial Reporting Standards[488] (IFRS) was created[489] based largely on US GAAP and UK GAAP.

The standardization of accounting terminology or jargon laid the foundation for representing accounting knowledge digitally. The standard terminology or jargon is the semantic layer needed for a domain of interest or an area of knowledge to be digitized and processed effectively using machine-based processes.

10.6. Knowledge-based systems

Knowledge representation[490] is the formal representation of knowledge such that the knowledge can be processed by a machine similar to how a human processes knowledge in the real world. In such a knowledge representation scheme, symbols are used as substitutes for real world artifacts within a domain of interest or area of knowledge.

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[485] David Ellerman, *The Mathematics of Double Entry Bookkeeping*, https://ellerman.org/wp-content/uploads/2012/12/DEB-Math-Mag.CV_.pdf

[486] CFA Institute, *US GAAP: Generally Accepted Accounting Principles*, https://www.cfainstitute.org/en/advocacy/issues/gaap#sort=%40pubbrowsedate%20descending

[487] Code of Federal Regulations, PART 210 - FORM AND CONTENT OF AND REQUIREMENTS FOR FINANCIAL STATEMENTS, SECURITIES ACT OF 1933, SECURITIES EXCHANGE ACT OF 1934, INVESTMENT COMPANY ACT OF 1940, INVESTMENT ADVISERS ACT OF 1940, AND ENERGY POLICY AND CONSERVATION ACT OF 1975, https://www.ecfr.gov/current/title-17/chapter-II/part-210

[488] CFA Institute, IFRS: International Financial Reporting Standards, https://www.cfainstitute.org/advocacy/issues/international-finance-reporting-stds

[489] Deloitte, Preface to International Financial Reporting Standards, https://www.iasplus.com/en/projects/completed/other/project89

[490] Knowledge Representation and Ontologies, Stephan Grimm, Pascal Hitzler, Andreas Abecker, https://www.aifb.kit.edu/images/9/94/2007_1644_Grimm_Knowledge_Repre_2.pdf

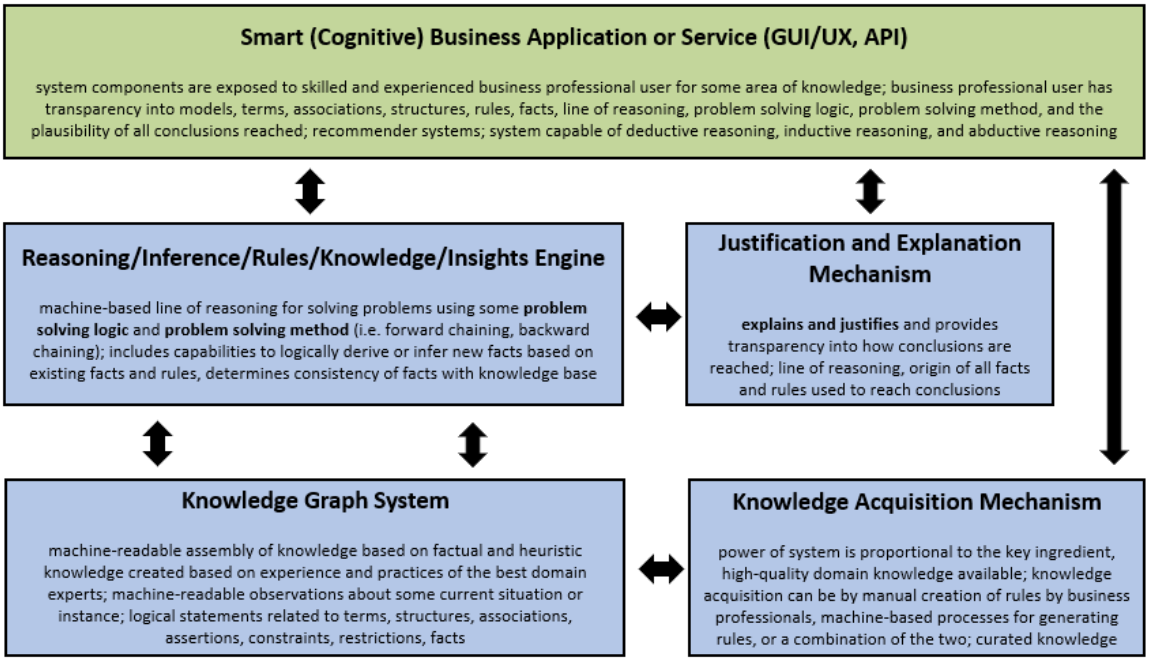
For example, the symbol "Assets" might be used to represent something for a computer to distinguish that thing from another thing referred to as "Liabilities" and another thing referred to as "Equity" in the domain of interest called accounting.

"Things" are represented formally as are "relations between things" and "rules" that things must follow. Facts can be described by the things, facts must follow the rules, and the relation between things form models that allow facts to be used in context with other facts.

Techniques of automated reasoning allow a machine, such as a computer system, to draw conclusions from the representations of knowledge. There are numerous approaches to representing knowledge. There are numerous approaches to implementing machine readable knowledge, different technical approaches that use physical formats that the machines actually read. There are different types of computer processes that can make use of information.

While the details of such machine-readable representations can be quite complex to understand, techniques exist, such as the creation of higher-level logical models, to hide the complexity of the representation from non-technical users in an area of knowledge, exposing those users only to the logic of their area of knowledge with which those users are perfectly comfortable with.

These systems are commonly referred to as knowledge-based systems (a.k.a. smart, cognitive, business applications or services). The following graphic shows the components of a knowledge-based system:



High level models can be used to abstract technical details away from the users of such systems enabling the systems to be used by experts within a specific area of knowledge or domain of interest.

Simply put, a knowledge-based system is a system that draws upon the knowledge of human experts for an area of knowledge that has been represented in machine-readable form and stored in a fact database and knowledge base. The system applies problem solving logic using a problem-solving method to solve problems that

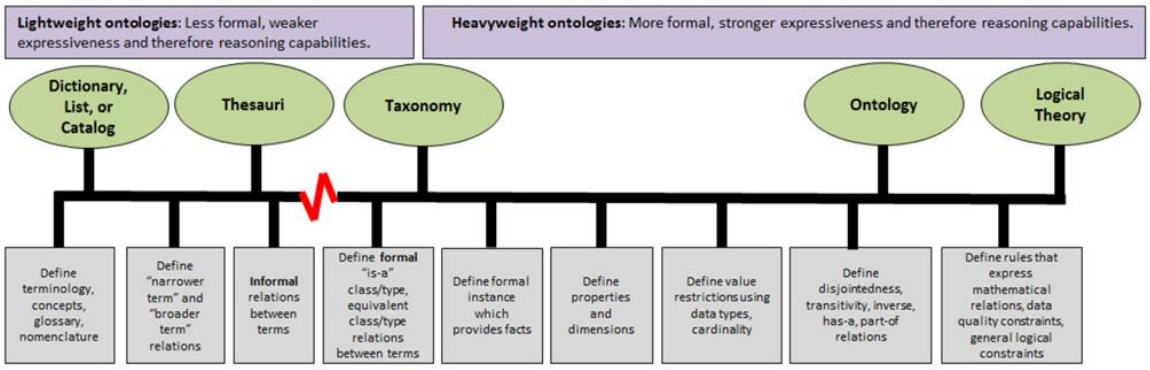
normally would require human effort and thought to solve. The knowledge-based system supplies an explanation and justification mechanism to help system users to understand the line of reasoning used and support conclusions reached by the knowledge-based system and presents that information to the user of the system.

While working with the low-level technical details can seem like working in computer assembly language to business professionals; business professionals never even need to see the technical details. Business professionals interact with the higher-level logical model, an abstraction layer that makes knowledge-based systems approachable to nontechnical business professionals.

Knowledge based systems augment a business professionals' skills similar to how a calculator augments someone's ability to do math. Machine and human collaborate, each performing the tasks that it does best.

10.7. Representing Knowledge in Machine Readable Form

The graphic below[491] is inspired by a similar graphic created by Deborah L. McGuiness and a graphic created by Dr. Leo Obrst. The intent of the graphic is to point out the spectrum of knowledge representation.



Inspired primarily by this graphic: Deborah L. McGuinness, *Ontologies for the Modern Age*, Slide 4, https://www.slideshare.net/deborahmcguinness/ontologies-for-the-modern-age-mcguinness-keynote-at-iswc-2017

Dr Leo Obrst, *Ontology Spectrum*, https://slideplayer.com/slide/697642/

The bottom line is that the most powerful approach to representing knowledge is the **logical theory**. Heavyweight logical theories are understandable to both technical professionals and business professionals such as accountants, auditors, and financial analysts. There are many different approaches that can be used to represent these logical theories such as ontologies + rules or graphs of nodes and edges or simply representing a set of logic connections[492].

But all this boils down to expressing the most logic possible as formally as possible as to maximize understandability which will maximize the potential functionality of software applications which can then be built to process that logical information.

But the power must be balanced with effectiveness. It is important that these powerful knowledge-based systems work reliably and predictably; they need to be free from catastrophic failures caused by things like logical paradoxes or infinite loops.

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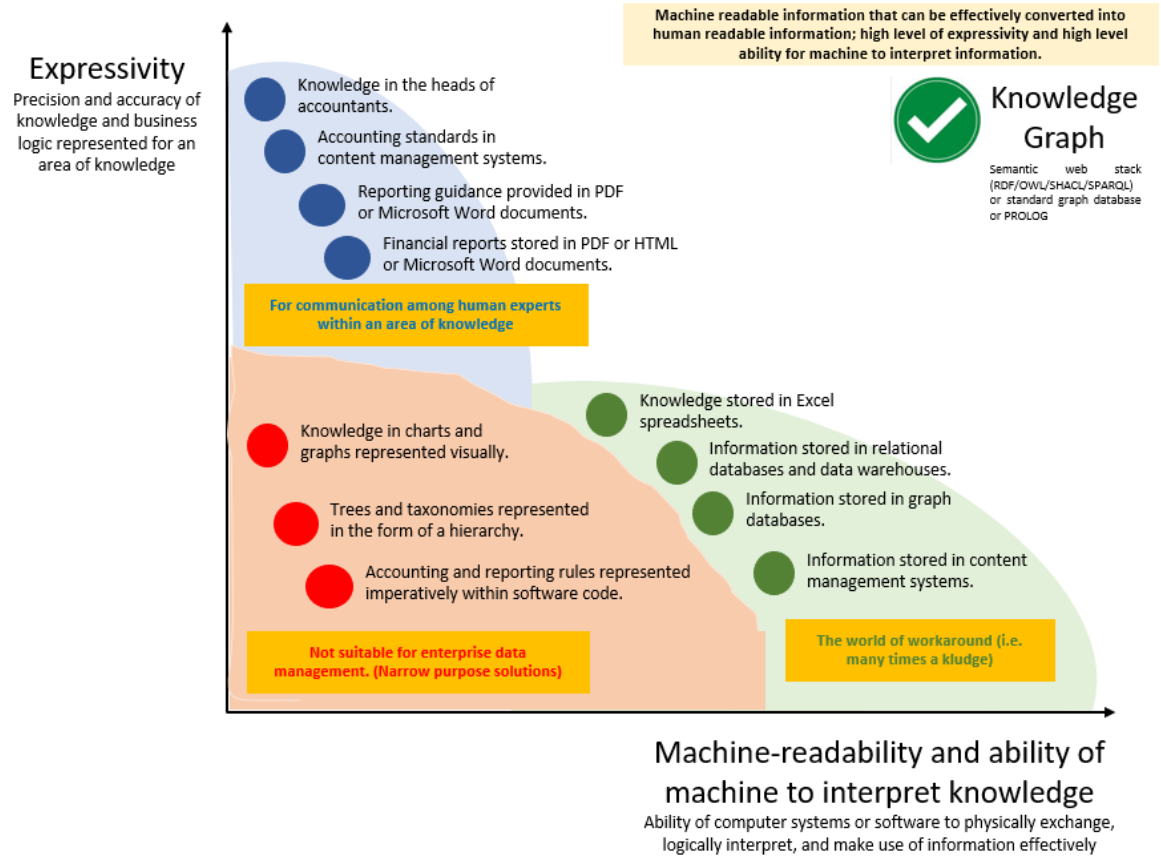
[491] Ontology Spectrum, http://xbrlsite.azurewebsites.net/2019/Library/OntologySpectrum.jpg
[492] Wikipedia, *Logical Connective*, https://en.wikipedia.org/wiki/Logical_connective

10.8. Logic and Knowledge Graphs

A knowledge graph (a.k.a. semantic network) represents the logic related to real-world entities (i.e., objects, events, situations, or concepts) and illustrates the relationship between them. Accountants have an innate understanding of logic. We communicate logic using knowledge graphs all the time. When you go to a whiteboard and draw circles and squares and connect them with lines with arrows you are drawing a graph and communicating knowledge. Those circles, squares, lines, and arrows are intuitively understandable and very expressive[493].

10.9. Digitizing the Knowledge in the Heads of Accountants

Inspired by a graphic that is general in nature provided in the article *Why Semantic Knowledge Graphs are the only way to build an Enterprise Data Fabric*[494]; I created this similar graphic that is more specific to accounting, reporting, auditing, and analysis. This graphic shows the relation between expressivity and machine-readability and therefore the fundamental ability of a machine to logically interpret and make use of information effectively:



[493] Charles Hoffman, CPA, *Logic and Knowledge Graphs*, http://www.xbrlsite.com/mastering/Part02_Chapter05.A1_LogicAndKnowledgeGraphs.pdf
[494] Medium.com, Boris Shalumov, *Why Semantic Knowledge Graphs are the only way to build an Enterprise Data Fabric*, https://shalumov-boris.medium.com/why-semantic-knowledge-graphs-are-the-only-way-to-build-an-enterprise-data-fabric-68f991eb4116

The bottom line here is that the financial accounting, reporting, auditing, and analysis knowledge needs to be, and will be, converted from human-readable artifacts into machine-readable artifacts that are also readable and usable by humans.

10.10. Acquiring Knowledge

A knowledge-based system for the area of knowledge of financial accounting, reporting, auditing, and analysis draws upon the knowledge of human experts, i.e.; accountants, auditors and analysts. High-quality curated knowledge can supercharge artificial intelligence applications. The more knowledge in the knowledge base, the more the knowledge-based system can do.

What is not in dispute is the need for a "thick metadata layer" and the benefits of that metadata in terms of getting a computer to be able to perform useful and meaningful work. This is simply science. But what is sometimes disputed, it seems, is how to most effectively and efficiently acquire that thick metadata layer.

So how exactly will all this knowledge in the heads of accountants be converted into machine-readable form? There are three fundamental approaches:

1. Machines do the conversions.
2. Humans do the conversions.
3. A combination of humans and machines do the conversions.

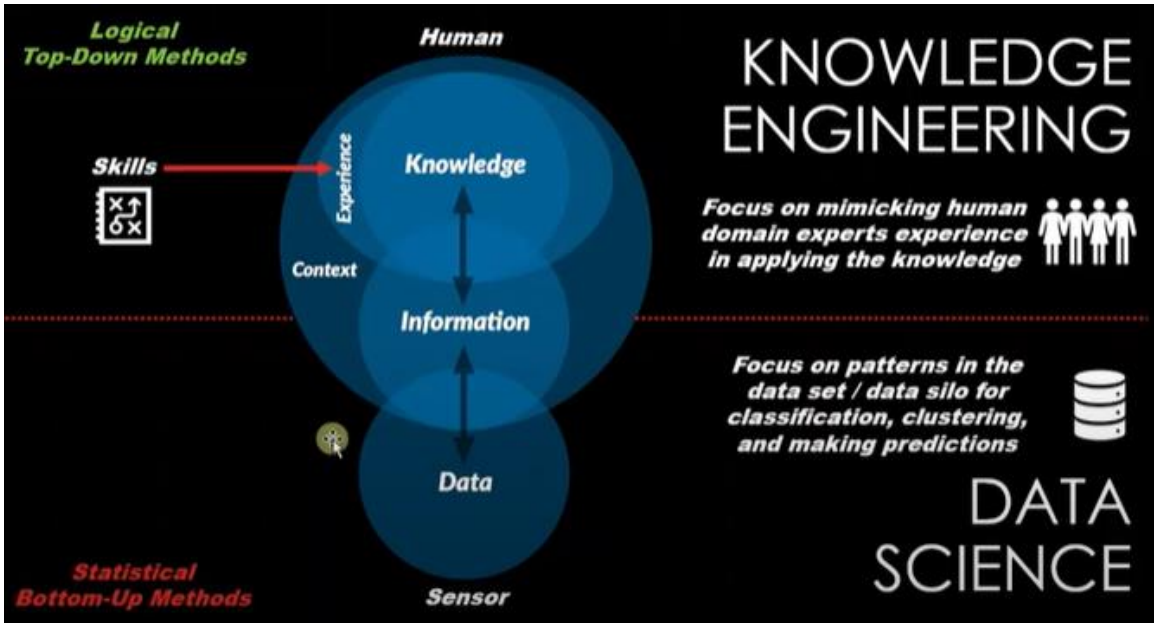
And not just anyone can convert human-readable information from human-readable form to machine-readable form. It takes a combination of the right skills and experience to get the job done right and the be able to maintain or curate the machine-readable information indefinitely. It also takes the proper tools; tools that the business professionals doing the work can relate to and use effectively.

Doing this right is like taking a raw material like a barrel of crude oil and refining it into high-octane racing fuel[495].

This graphic below helps one understand how knowledge acquisition can be achieved[496]:

[495] Understanding the Power of Classification, http://xbrl.squarespace.com/journal/2019/5/14/understanding-the-power-of-classification.html

[496] LinkedIn, Shawn Riley, *Machine Learning vs. Machine Understanding*, https://www.linkedin.com/pulse/machine-learning-vs-understanding-shawn-riley/



To get the right result, you need to use the right tool. There is zero probability that machine learning will "auto-magically" create the rich set of machine-readable information necessary for financial accounting, reporting, auditing, and analysis.

The complexity of knowledge engineering needs to be made invisible to the business professionals using knowledge engineering software. This is done by taking general functionality and specializing it for specific areas of knowledge rather than forcing business professionals to learn knowledge engineering. This is not about creating simplistic tools; this is about working very, very hard to burry complexity and create easy to use tools[497].

A kluge is a term from the engineering and computer science world, it refers to something that is convoluted and messy but gets the job done. Anyone can create something that is complex. Anyone can create a kludge. But it is hard work to create something that is simple and elegant.

Key to leveraging artificial intelligence is beating down complexity and exposing business professionals to the logic of their area of knowledge which they innately understand.

10.11. Intelligence

Intelligence[498] is the ability to perceive or infer information and reason with respect to that information using a known logic and known reasoning approaches and to retain that information as knowledge to be applied towards achieving specified goals and objectives within a specified environment or context (a.k.a. formal defined system with specified and known boundaries agreed to by a known set of stakeholders).

[497] Understanding the Law of Conservation of Complexity, http://xbrl.squarespace.com/journal/2015/5/24/understanding-the-law-of-conservation-of-complexity.html
[498] Intelligence, https://digitalfinancialreporting.blogspot.com/2024/04/intelligence.html

Intelligence is "human-task" performance. Intelligence is defined by the "formalism" of a rules-based system or process; the task of set of tasks that must be performed. Basically a "machine" (e.g. computer or other apparatus) for performing human tasks agreed to by a known group of stakeholders and the system has known goals and objectives. In essence, this is a formal system with specific boundaries and the system is blind to something not covered by the rules of that specific defined system.

I am going to classify intelligence into two groups:

- Human-intelligence.
- Machine-intelligence.

I would contend that it is a fool's errand to try and compare machine-intelligence to human-intelligence. They are not even in the same ballpark and they won't be for a long time, if ever. The notion of "superintelligence" in computers is a fantasy. Computers are nowhere close to achieving superintelligence which I would consider as being human-level intelligence or higher levels of intelligence beyond the capabilities of humans.

If you are interested in this topic, I would highly recommend the book *The Myth of Artificial Intelligence*[499] which analyzes these ideas in great detail in a very approachable way.

10.12. Artificial Intelligence (a.k.a. machine intelligence)

There are two approaches to implementing artificial intelligence (a.k.a. machine intelligence) and the right approach should be used for the given job[500]. The two approaches are:

1. **Rules-based systems** (expert systems, three basic types)
    - **Classification or diagnosis type**: helps users of the system select from a set of given alternatives.
    - **Construction type**: helps users of the system assemble something from given primitive components.
    - **Simulation type**: helps users of the system understand how some model reacts to certain inputs.
2. **Patterns-based systems** (machine learning which is probability based and can be supervised or unsupervised, five basic types[501])
    - **Clustering algorithms**: categorize or group things
    - **Explanatory algorithms**: explain the relationships between variables
    - **Ensemble learning algorithms**: uses multiple models
    - **Similarity algorithms**: compute the similarity of pairs of things

[499] Amazon, *The Myth of Artificial Intelligence*, https://www.amazon.com/Myth-Artificial-Intelligence-Computers-Think/dp/B09HSLLFD3/
[500] *Use the Right Artificial Intelligence Approach for the Job*, http://xbrl.squarespace.com/journal/2019/7/12/use-the-right-artificial-intelligence-approach-for-the-job.html
[501] EDUCBA, Machine Learning Models, https://www.educba.com/machine-learning-models/

- **Dimensionality reduction algorithms**: reduces variables in a dataset

You can combine both approaches and create a third approach which is a hybrid of both approaches. Each approach has its pros and cons.

GPT-4 and large language models (LLM) which is the technology between ChatGPT[502] is a type of patterns-based system.

Artificial intelligence officially began as a discipline of computer science in 1956. Artificial intelligence involves creating tools such as algorithms, models, architectures, and software that simulate cognitive processes; basically, intelligent machines. Artificial intelligence or AI is an umbrella term that covers many tools or "tribes" building tools to implement artificial intelligence within computer systems. These "tribes" or tools include:

- **Symbolic systems also known as "Good Old-Fashioned AI" (GOFAI)**: These techniques involve explicitly programming logical rules and other logic into machines. Effectively, this is logical programming such as PROLOG and LISP. (*Handcrafted knowledge or rules-based systems*)
- **Machine Learning (ML)**: This is a subfield of AI that allows computers to learn without explicit programming. Machines learn by analyzing data and identifying patterns and clustering those patterns into groups. It then uses what it has learned to make decisions or predictions. (*Statistical learning or pattern-based systems*)
    - **Deep Learning (DL)**: Deep learning is a specific type of machine learning inspired by the structure and function of the brain. It uses artificial neural networks with many layers to learn complex patterns from data.
    - **Transformers**: Transformers are a type of neural network architecture commonly used in deep learning. These are a specific kind of neural network architecture well-suited for handling sequences like text. They are particularly good at understanding the relationships between words in a sentence.
    - **Large Language Models (LLMs)**: LLMs are a type of machine learning. LLMs often rely on transformers for their processing. These are advanced machine learning models trained on massive amounts of text data. They can perform many kinds of tasks with language, including generating text, translating languages, writing different kinds of creative content, and answering your questions in an informative way that is natural to humans.
    - **Generative AI**: Generative AI is a type of machine learning that learns from existing examples including text, images, videos, music and then create new, realistic content that reflects the patterns it learned from the examples.

[502] ChatGPT, https://digitalfinancialreporting.blogspot.com/2022/12/someone-made-me-aware-of-chatgpt-couple.html

- **Natural Language Processing (NLP)**: NLP focuses on enabling computers to understand, interpret, and generate human language. NLP bridges the gap between raw text data and meaningful insights. LLMs, such as GPT (Generative Pre-trained Transformer), leverage NLP techniques to understand and generate human-like text.

There are many other aspects to artificial intelligence such as explainable artificial intelligence or XAI[503]. AI approaches can be combined to create hybrids. Humans and machines can be brought together, each bringing their unique capabilities to the table to solve problems and perform tasks or complete processes.

DARPA and PWC do an excellent job of explaining the capabilities of artificial intelligence. This presentation[504], video[505] and this article[506] provide a summary worth reading.

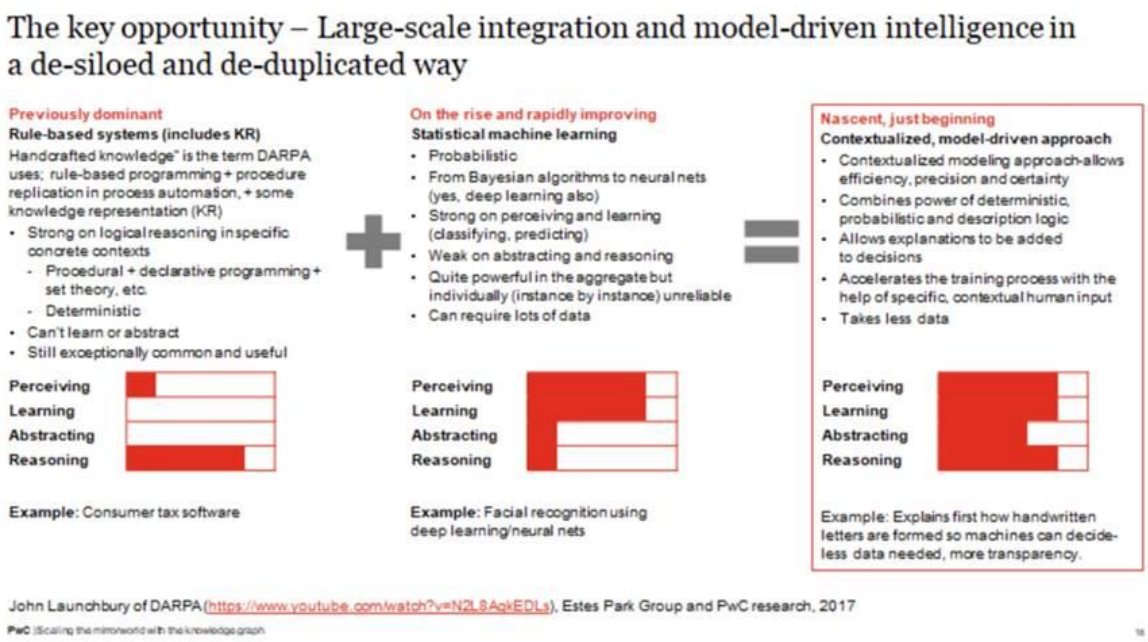
10.13. Programmed Ability to Process Information

Again, the more knowledge in a knowledge-based system, the more the knowledge-based system can do for the users of the system. This is not necessarily an "either/or" type decision. If rules-based and patterns-based systems are properly combined, the most powerful result can be achieved.

Alan Morrison explains the differences and the possibilities in the article, *What is the relation between Semantic Web and AI*?[507] The best solution with the most power combines that capabilities of rules-based and statistical-based pattern-based systems.

This graphic from that article helps to communicate the possibilities:

[503] ACCA, Explainable Artificial Intelligence, https://www.accaglobal.com/uk/en/professional-insights/technology/Explainable_AI.html
[504] DARPA, *A DARPA Perspective on Artificial Intelligence*, https://www.darpa.mil/attachments/AIFull.pdf
[505] YouTube.com, *A DARPA Perspective on Artificial Intelligence*, https://youtu.be/-O01G3tSYpU
[506] Quora, Alan Morrison, *What is the relation between Semantic Web and AI?*, https://www.quora.com/What-is-the-relation-between-Semantic-Web-and-AI/answer/Alan-Morrison?ch=2&oid=180785119&srid=Mru&target_type=answer
[507] Quora, Allan Morrison, What is the relation between Semantic Web and AI?, https://www.quora.com/What-is-the-relation-between-Semantic-Web-and-AI/answer/Alan-Morrison



Both over estimating and under estimating the capabilities of artificial intelligence have negative consequences. *The AI Ladder*[508], by Rob Thomas and published by O'Reilly Media, is by far the best resource that I have run across related to getting your head around artificial intelligence. Here is a summary of why AI projects fail:

- **Lack of understanding**. 81% of business leaders to not understand AI.
- **Bad data**. Not having a handle on your data is completely paralyzing. Your AI is only going to be as good as your data.
- **Lack of the right skills**. The lack of the right skills on part of both business professionals and information technology professionals is problematic.
- **Trust**. Trusting the recommendations made by your artificial intelligence software is a must. AI should not be a black box; business professionals need justification mechanisms that support conclusions.
- **Culture**. *The Technology Fallacy*[509] points out that digital transformation involves changes to organizational dynamics and how work gets done. AI will enable entirely new business models which were impossible in the past.

Implementing AI is hard work. Getting AI right involves the right tools, the right skills, and the right mindset.

Similar to how a calculator augments the capabilities of an accountant to do math; artificial intelligence will augment the skills and capabilities of accountants, auditors, and analysts. But artificial intelligence must make things better, faster, and/or cheaper to be useful.

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[508] O'Reilly Media, Rob Thomas, *The AI Ladder*, https://www.oreilly.com/online-learning/report/The-AI-Ladder.pdf

[509] Deloitte, Gerald C. Kane, Anh Nguyen Phillips, Jonathan R. Copulsky, and Garth R. Andrus, *Technology Fallacy*, https://www2.deloitte.com/us/en/pages/human-capital/articles/the-technology-fallacy.html

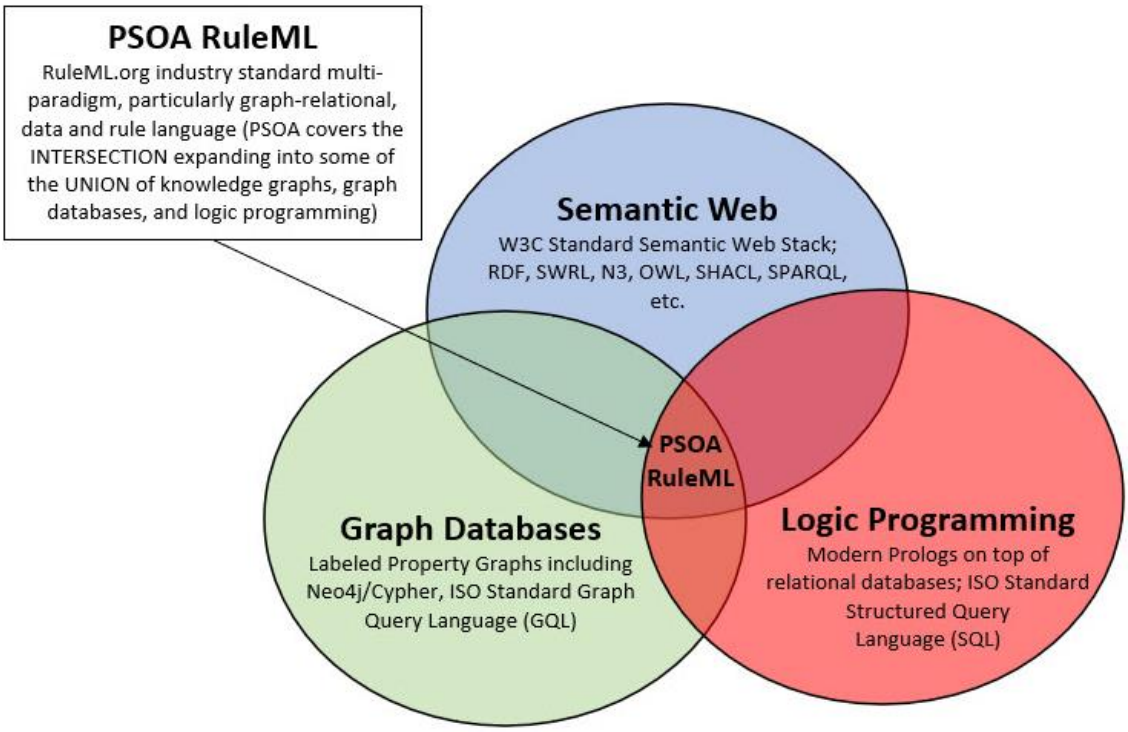
Accounting, reporting, auditing, and analysis cannot be a black box. Explainable AI (XAI)[510] is necessary. Explainable artificial intelligence (XAI) emphasizes the capabilities of the algorithm not just in providing an output, but also in sharing with the user the supporting information relating to the line of reasoning used by the system to reach the conclusion it reached.

10.14. Implementing Knowledge Graphs in Software

All that accounting knowledge that is created by skilled accountants with many years of experience needs to be physically represented using some technical format in some form. That machine readable information once created needs to be maintained and otherwise curated to keep the knowledge in usable form and correct. Software also needs to be able to effectively process that knowledge without catastrophic failure of the software.

The different technical approaches for physically creating this machine-readable knowledge tends to take one of three forms[511]. Those forms are: Semantic Web, Graph Databases, and Logic Programming.

The following graphic shows these three approaches but more importantly it points out that each of the approaches can be converted to the other approaches quite easily, or could if the logical information represented within by any approach is within the bounds of what can be represented by the other two technical formats.



[510] ACCA, *Explainable AI: Putting the user at the core*, https://www.accaglobal.com/uk/en/professional-insights/technology/Explainable_AI.html
[511] Implementing Knowledge Graphs, http://xbrl.squarespace.com/journal/2021/9/20/implementing-knowledge-graphs.html

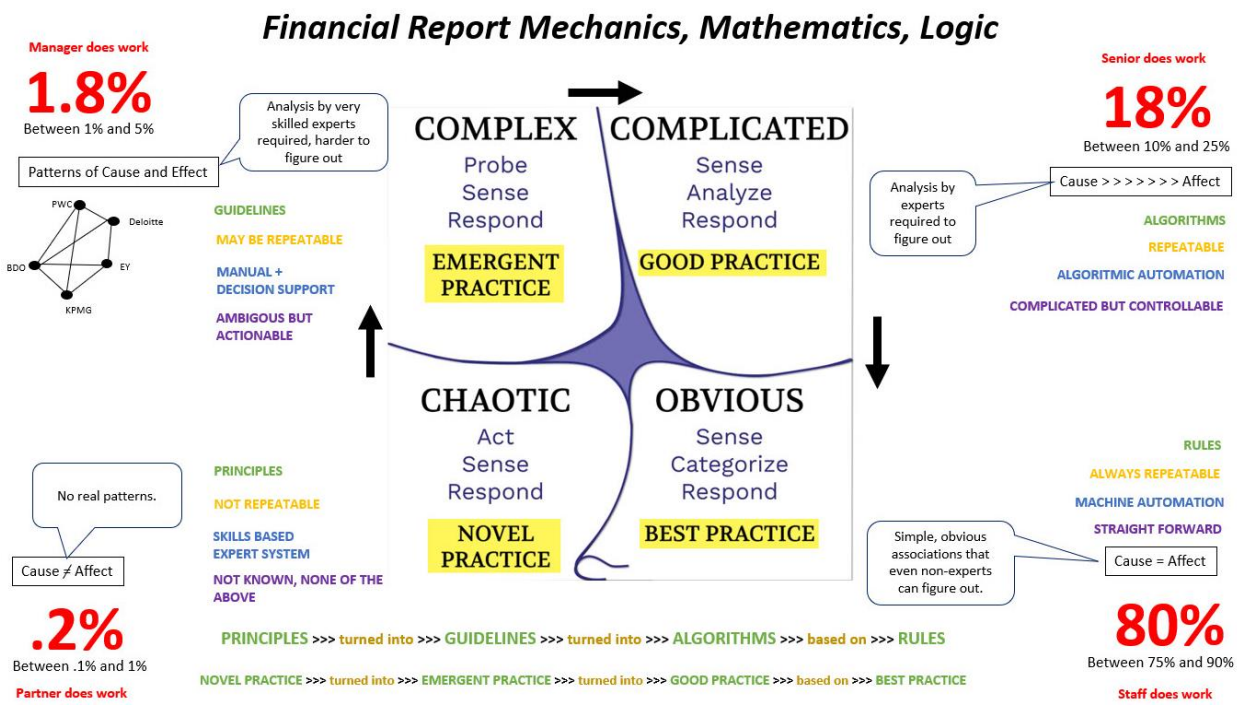
10.15. Sensemaking

Financial accounting, reporting, auditing, and analysis is an area of knowledge. Sensemaking[512] is the process of determining the deeper meaning or significance or essence of the collective experience for those within an area of knowledge.

The Cynefin Framework[513] is a model for performing sensemaking.

Applying the Cynefin Framework to the area of knowledge of accounting, reporting, auditing, and analysis helps one understand that knowledge can be put into machine readable form.

[512] Sensemaking, http://xbrl.squarespace.com/journal/2021/11/18/sensemaking.html
[513] YouTube.com, *The Cynefin Framework*, https://www.youtube.com/watch?v=N7oz366X0-8



The bottom line is that more knowledge can be put into machine readable form than you might think. That said, computers have their limitations. In the future, humans should do what humans do best and computers should do what computers do best.

10.16. Logical Theory is an Approach to Agreeing

A logical theory enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important logical statements used for capturing meaning or representing a shared understanding of and knowledge in some area of knowledge.

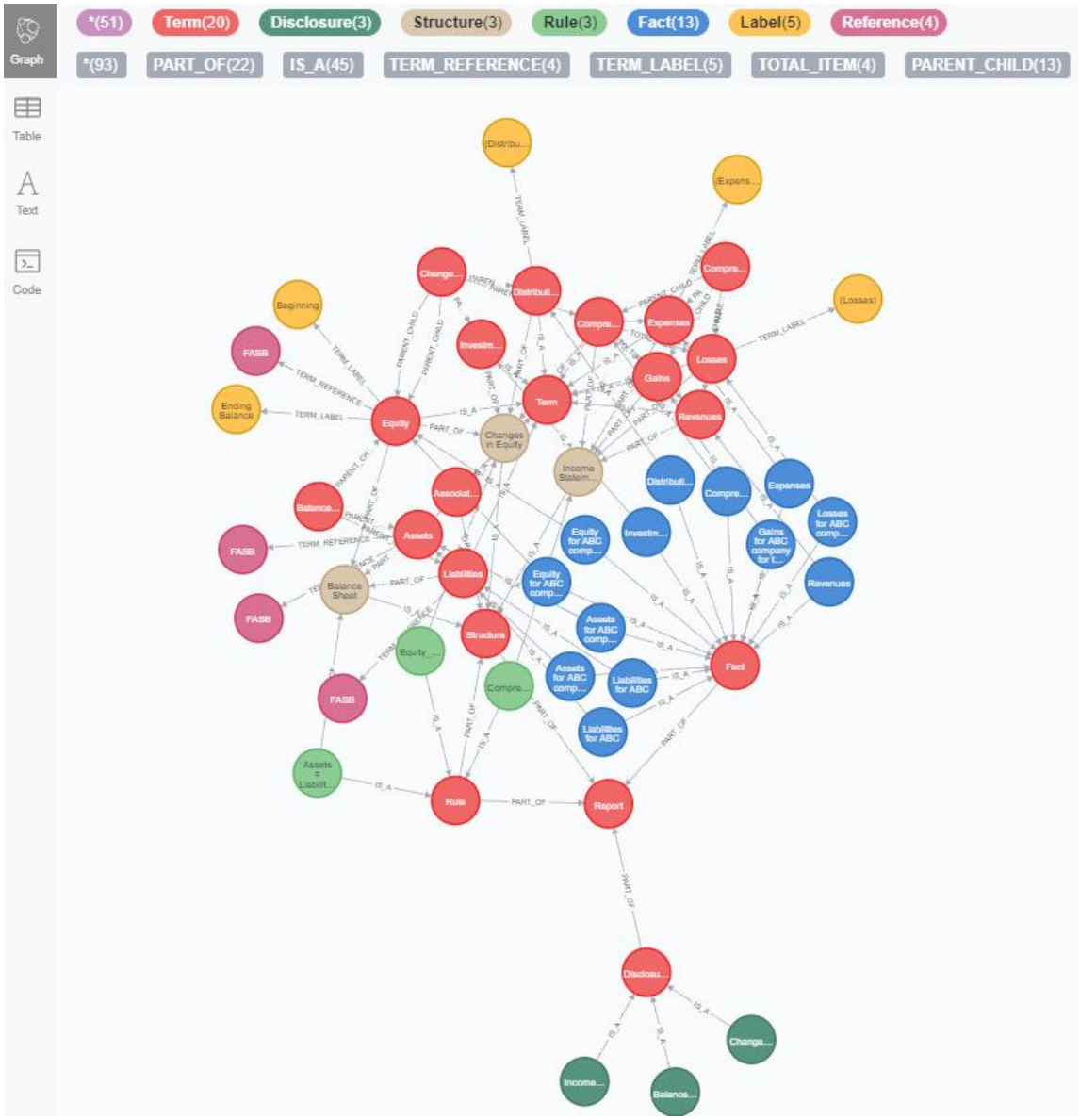
The objective is to agree in order to achieve a goal or range of goals. Fundamentally, it is the conscious intension of this logical system to safely, reliably, and otherwise successfully communicate information. The stakeholders fundamentally agree to eliminate all possible features that introduce potential failure and to leverage all possible features that lead to provable success.

10.17. Logical Theory Describing Financial Report

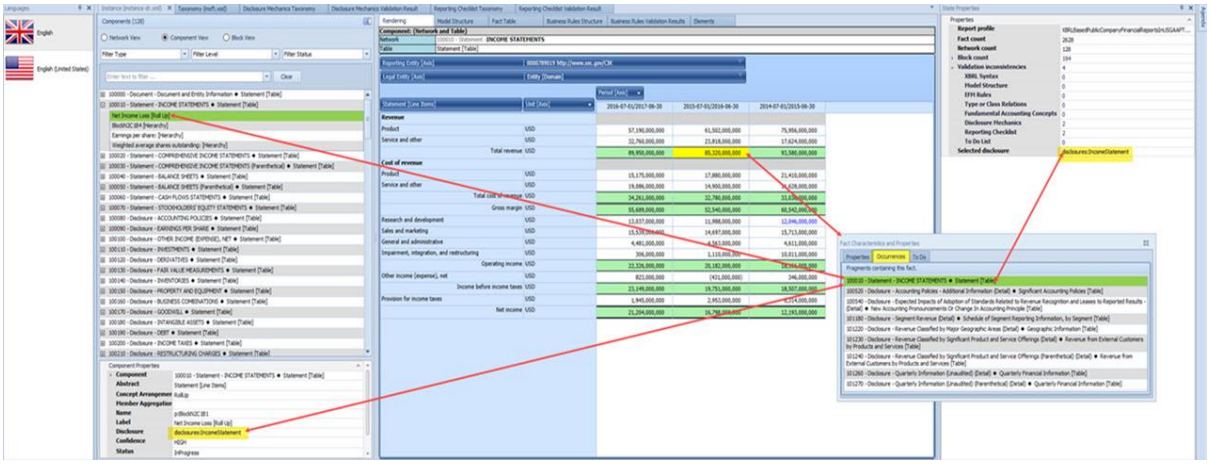
A financial report can be thought of as a knowledge graph[514]. Using properly functioning software, that knowledge graph can be converted into many different forms depending on whether a human is using the information or whether a machine is using the information.

And so, a knowledge graph might look like this for a machine to use:

[514] Financial Report Knowledge Graph, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf



And the same information might look like this for a human to make use of:



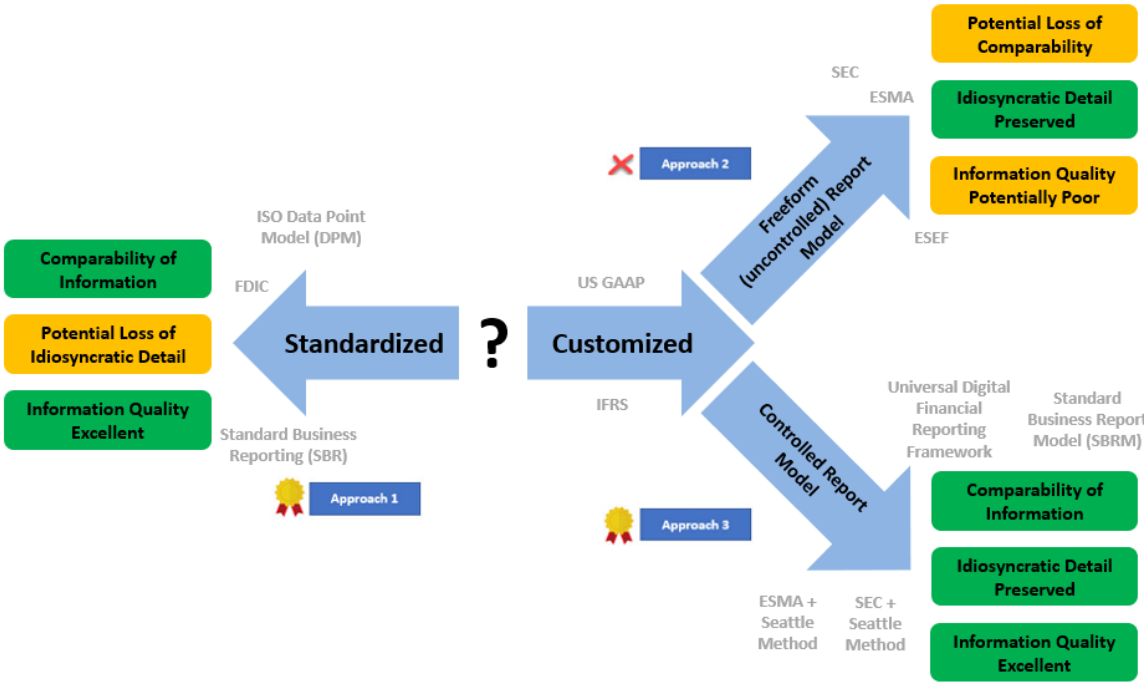
10.18. Control and Flexibility

US GAAP and IFRS based financial reports are not forms. The *Seattle Method*[515] is an approach to managing flexibility. The *Seattle Method* is a proven, industrial strength, good practices, standards-based pragmatic approach to creating provably high quality XBRL-based general purpose digital financial reports when reporting entities are permitted to modify the report model.

The focus of the *Seattle Method* is financial reporting using financial reporting schemes such as US GAAP, IFRS, UK GAAP, and other schemes where the preparer of a financial report is permitted to modify the report model. Because modification of the report model is allowed, those modifications must be controlled to keep the modifications within permitted boundaries.

Without control, there can be no automation, no repeatable processes. Rules provide control. Control leads to high quality. High quality leads to effective automation. Accountants manage the rules.

[515] *Seattle Method*, http://xbrlsite.com/seattlemethod/SeattleMethod.pdf



Machine readable rules are used to control systems. In addition, the rules describe the system and are available for software applications to use in order to provide functionality to using software to interact with machine readable financial reports. Rules do the following:

- Elimination of "**wild behavior**" by accountants when report model can be modified
- **Description** of report (specification of what is permitted); created by standards setter or regulator or anyone else specifying a report
    - Machine ***readable form***
    - Machine readable form converted to ***human readable form***
- **Create** report based on description (assisted by software utilizing machine readable description)
- **Verify** that report has been created per description (assisted by software utilizing machine readable description)
- **Extract** information from report per report description (assisted by software utilizing machine readable description)
    - Properly Functioning Logical System

In her book *An Introduction to Ontology Engineering*[516], C. Maria Keet, PhD, provides a discussion about what constitutes a good and perhaps a not-so-good ontology. These ideas are also applicable to knowledge graphs. There are three categories of errors she discusses:

[516] C. Maria Keet, PhD, *An Introduction to Ontology Engineering*, PDF page 23, https://people.cs.uct.ac.za/~mkeet/files/OEbook.pdf#page=23

- **Syntax errors**: She discusses the notion that a syntax error in an ontology is similar to computer code not being able to compile. For example, when an XBRL processor tells you that your XBRL taxonomy is not valid per the XBRL technical specification.
- **Logic errors**: She discusses the notion of logical errors within information which cause the information to not work as expected. For example, if you represented something in your XBRL taxonomy as a credit when it should have been a debit.
- **Precision and coverage errors**: Finally, Keet discusses the notions of precision and coverage when it comes to judging whether information is good or bad. If information is left out then software cannot tell you if what you have represented is right or wrong. If your underlying facts are not precise, then while a machine can tell you that your representation is precise per the represented facts but it cannot understand that the underlying facts are wrong.

Precision is a measure of how precisely the information within a logical theory has been represented as contrast to reality of the logical system for the area of knowledge. *Coverage* is a measure of how completely information in a logical theory has been represented relative to the reality of the logical system for the area of knowledge.

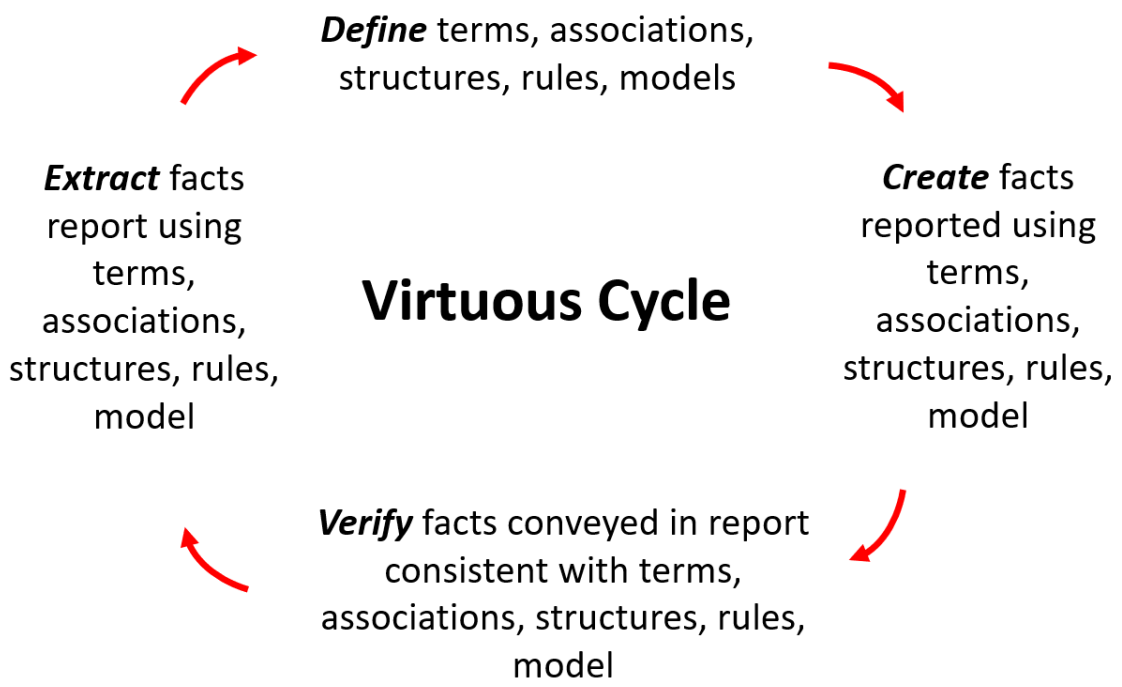
Keet uses those terms, others use different terms including sound, complete, and effective to describe a well-functioning logical system. There are other descriptions as well. The following is the description that I will use.

A logical theory can be used to describe a logical system. A logical system is said to be **consistent** with a logical theory if there are no contradictions with respect to the logical statements made by the logical theory that describes the logical system.

A logical theory can have high to low **precision** and high to low **coverage** with respect to describing a logical system.

When a logical system is consistent and it has high precision and high coverage the logical system can be considered a **properly functioning logical system**. When a logical system is properly functioning, it creates a virtuous cycle[517]. This cycle is controlled using the complete set of rules.

[517] Charles Hoffman, CPA, *Virtuous Cycle*, http://xbrl.squarespace.com/journal/2020/4/29/virtuous-cycle.html



A logical theory conveys knowledge and that knowledge can be represented within a knowledge graph. For more detailed information related to logical theories and logical systems, please see *Logical Systems*[518].

10.19. Standing on the Shoulders of Giants

The point is to create a logical system that has high expressive capabilities but is also a provably safe and reliable system that is free from catastrophic failures and logical paradoxes which cause the system to completely fail to function. The system is controlled. To avoid failure, computer science and knowledge engineering best practices seems to have concluded that the following alternatives are preferable:

- **Systems theory**: A system[519] is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Systems theory explains logical systems. Systems have patterns.
- **Logical theory**: There are many approaches to representing logical systems in machine-readable form, a logical theory being the most powerful (ontology + rules). A logical theory explains a logical conceptualization. Theories describe patterns. (see the ontology spectrum[520])

[518] Charles Hoffman, CPA, *Logical Systems*, http://www.xbrlsite.com/mastering/Part02_Chapter05.A_LogicalSystems.pdf
[519] Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory
[520] *Difference between Taxonomy, Conceptual Model, Logical Theory*, http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html

- **Proof theory**: The ideas of proof theory[521] can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems using mathematics[522]. Proofs verify theories. Machine readable logical theories can be proven using automated processes.
- **Model theory**: Model theory is a way to think about flexibility. Safer finite model theory[523] is preferable to general model theory. Models provide flexibility.
- **Set theory**: Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory[524] is preferred to naïve set theory.
- **Graph theory**: Directed acyclic labeled property graphs[525] are preferred to less powerful "trees" and graphs which contain cycles that can lead to catastrophic problems caused by those cycles.
- **Logic**: Logic is a formal communications tool. Horn logic[526] is a subset of first-order logic and is the basis for Prolog[527]. Datalog[528] is a subset of Horn logic (function free PROLOG) which is immune from logical paradoxes should be used as contrast to more powerful but also more potentially problematic first order logic features. Note that deductive reasoning is leveraged for the process of creating a financial report and not inductive reasoning (i.e. machine learning). Datalog is the logic used by SQL.
- **World view**: The following are common issues which appear when implementing logical systems which exchange information in machine-readable form, the safest and most reliable alternatives are:
    - **closed world assumption**[529] (used by relational databases) is preferred to the open world assumption which can have decidability issues;
    - **negation as failure**[530] (used by relational databases) should be explicitly stated;
    - **unique name assumption**[531] (used by relational databases) should be explicitly stated;

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[521] Stanford University, *The Development of Proof Theory*, *The Aims of Proof Theory*, https://plato.stanford.edu/entries/proof-theory-development/#AimProThe
[522] Samuel R. Buss, *An Introduction to Proof Theory*, https://math.ucsd.edu/~sbuss/ResearchWeb/handbookI/ChapterI.pdf
[523] Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory
[524] Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory
[525] Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph
[526] Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause
[527] Wikipedia, *Prolog*, https://en.wikipedia.org/wiki/Prolog
[528] Wikipedia, *Datalog*, https://en.wikipedia.org/wiki/Datalog
[529] Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption
[530] Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure
[531] Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption

- **Dimensional fact model**: The dimensional fact model[532] provides a clear and exhaustive representation of multidimensional concepts. XBRL Dimensions specifies a dimensional fact model.
- **Logical Theory Describing Financial Report**: The *Logical Theory Describing Financial Report*[533] is a logical conceptualization of the mechanical, mathematical, structural, and other such logical aspects of general purpose and special purpose financial reports for the purpose of representing such reports digitally using XBRL and other technical syntaxes.
- **Standard Business Report Model (SBRM)**: The Standard Business Report Model (SBRM)[534] formally documents a logical conceptualization of a business report in both human-readable and machine-readable models.
- **XBRL technical syntax physical format**: The Extensible Business Reporting Language (XBRL)[535] is the international standard for the electronic representation of business reports. A financial statement is a specialization of the more general business report.

These theories, models, techniques, and principles have been created over many years and must be considered when trying to implement knowledge-based systems related to financial accounting, reporting, auditing, and analysis.

10.20. Algorithmic Regulation

So why is all this important? ***The Great Transmutation*** is about a paradigm shift in financial accounting, reporting, auditing, and analysis. People refer to this paradigm shift in different ways. Here are how some people package this paradigm shift:

- MIT refers to this as **Algorithmic Business Thinking**[536]
- Carnegie Mellon University refers to this as **Computational Thinking**[537]
- Harvard University refers to this as **Regulation, the Internet Way**[538]
- Vanderbilt University refers to this as **Regulation 2.0**[539]
- The Data Coalition calls this **Smart regulation**[540]

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[532] Wikipedia, Dimensional Fact Model, https://en.wikipedia.org/wiki/Dimensional_fact_model
[533] Charles Hoffman, CPA, *Logical Theory Describing Financial Report (Terse)*, http://xbrlsite.com/seattlemethod/LogicalTheoryDescribingFinancialReport_Terse.pdf
[534] OMG, *Standard Business Report Model (SBRM)*, https://www.omg.org/intro/SBRM.pdf
[535] XBRL International, XBRL Essentials, https://specifications.xbrl.org/xbrl-essentials.html
[536] MIT, Accelerating Digital Transformation with Algorithmic Business Thinking, https://executive.mit.edu/course/accelerating-digital-transformation-with-algorithmic-business-thinking/a056g00000URaaQAAT.html
[537] Carnegie Mellon Center for Computational Thinking, https://www.cs.cmu.edu/~CompThink/
[538] Harvard University, Regulation, the Internet Way, https://datasmart.ash.harvard.edu/news/article/white-paper-regulation-the-internet-way-660
[539] SSRN, *Regulation 2.0: The Marriage of New Governance and Lex Informatica*, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2746229
[540] Smart Regulation, http://xbrl.squarespace.com/journal/2012/11/12/smart-regulation-graphic-shows-the-big-picture.html

- Tim O'Reilly Founder and CEO O'Reilly Media Inc. calls it **Algorithmic regulation**[541]
- Deloitte refers to this as "**The Finance Factory**" and **Digital Finance**[542]
- Robert Kugel of Ventana Research calls it "**Digital Finance**"[543]
- The government of Norway calls this "**Nordic Smart Government and Business**"[544]

I refer to all this as **Computational Professional Services**[545]. (There might be a better term, but that is the term I am currently using).

Imagine a set of high-quality knowledge graphs organized into the form of a knowledge portal[546]. Imagine that the knowledge portal is enhanced by blockchain technology. Imagine that the knowledge graphs physical syntax is based on global standards and that the information within those knowledge graphs is also based on standards.

Imagine a system that is simple and elegant to use, rather than a poorly thought-out kludge.

Trying to understand what is going on by trying to plug the changes that you see into the current paradigm of accounting, reporting, auditing, and analysis is like walking around the city of Chicago with a map of New York City to try and find your way. Using the appropriate map, such as a map of New York City, would work better.

10.21. Need for a New Type of Spreadsheet

The traditional electronic spreadsheet is a very useful tool. The electronic spreadsheet has been around for more than 40 years, an indispensable tool of accountants, auditors, and analysts. They are the right tool for many situations. But they are not the right choice in other situations. Also; the process of creating financial reports tends to be inefficient, error prone, described as an old school manual process.

The average Fortune 1000 company, Gartner Research says, uses approximately 800 spreadsheets in the process of creating external financial statements submitted for regulatory reporting.

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[541] Tim O'Reilly Founder and CEO O'Reilly Media Inc., Open Data and Algorithmic Regulation, https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/
[542] Deloitte, *Finance 2025: Digital transformation in finance*
Our eight predictions about digital technology for CFOs,
https://www2.deloitte.com/us/en/pages/finance-transformation/articles/finance-digital-transformation-for-cfos.html
[543] Robert Kugel, *The Rising Expectations for Finance Analytics*,
https://www.linkedin.com/pulse/rising-expectations-finance-analytics-robert-kugel/
[544] Nordic Smart Government and Business, https://nordicsmartgovernment.org/
[545] Computational Professional Services,
http://www.xbrlsite.com/mastering/Part00_Chapter01.A1_ComputationalProfessionalServices.pdf
[546] Data Science Central, Kurt Cagle, *From Knowledge Graphs To Knowledge Portals*,
https://www.datasciencecentral.com/from-knowledge-graphs-to-knowledge-portals/

How can the electronic spreadsheet be described as such a useful tool but also be part of such inefficient and error prone processes? Sure, electronic spreadsheets are a vast improvement over paper-based spreadsheets.

But is there a "better spreadsheet"? Is there a more modern approach, a "modern spreadsheet" that could overcome some of the limitations and inherent risks of the contemporary electronic spreadsheet?

I think that there is and I have summarized my thoughts in the document *Special Purpose Logical Spreadsheet for Accountants*[547], a call for a more modern professional tool for accountants, auditors, and analysts which addresses the significant limitations and inherent risks when making use of traditional electronic spreadsheets.

Modern, professional, logic-oriented machine-readable and machine-understandable global standard spreadsheets will serve as the building blocks; think "Legos"; of modern accounting information systems[548].

Imagine a modern working trial balance[549] that is the foundation of every complication, review, or audit of a financial report. Imagine semantic oriented accounting and auditing working papers and schedules[550]. Imagine financial analysis models driven by logic rather than layout.

Creating a financial report today is like constructing a machine before the invention of interchangeable parts[551]. It took a highly skilled craftsmen to create anything. If something broke, it took a highly skilled craftsmen to fix the problem or create a replacement part.

An interchangeable part is a part or component that is created to a specific specification and is identical to other parts and will fit into an assembly that requires that part/component. No customization was required to make the part/component fit into the assembly. This enables easy assembly, a reduction in the skills required to assemble, easier repair, which minimizes time and cost.

The Fourth Industrial Revolution demands better tools for working with the ever increasing volume and complexity of information. The traditional electronic spreadsheet will not go away, it still has value. But perhaps 20% of the things traditional electronic spreadsheets are used for demand better, more professional oriented tools.

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[547] Charles Hoffman, CPA, Special Purpose Logical Spreadsheet for Accountants, http://www.xbrlsite.com/2023/Library/SpecialPurposeLogicalSpreadsheetsForAccountants.pdf
[548] Universal Global Standard Logical Spreadsheet (Professional Spreadsheet), https://digitalfinancialreporting.blogspot.com/2023/05/universal-global-standard-logical.html
[549] Modern Working Trial Balance, https://digitalfinancialreporting.blogspot.com/2023/05/modern-working-trial-balance.html
[550] Semantic Accounting and Auditing Working Papers, https://digitalfinancialreporting.blogspot.com/2023/05/semantic-accounting-and-auditing.html
[551] Interchangeable Parts: Information Lego Blocks, https://digitalfinancialreporting.blogspot.com/2023/05/interchangeable-parts-information-lego.html

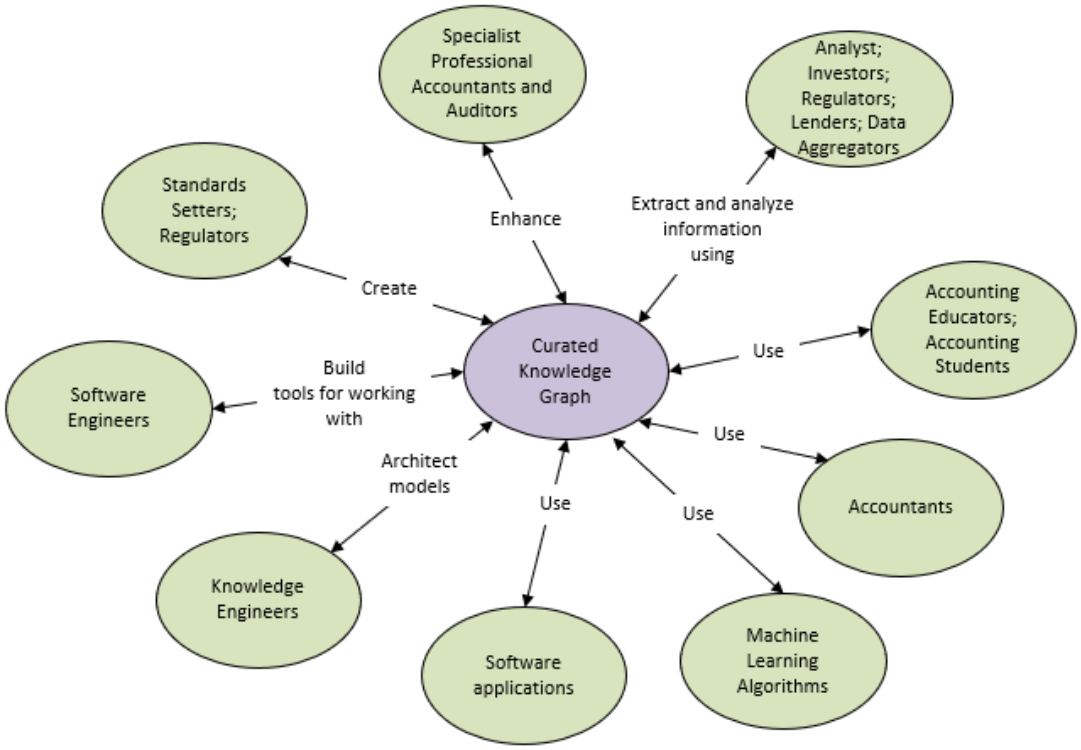
10.22. Need for Clarity

A financial reporting scheme represented digitally using an XBRL taxonomy which is then used to represent a report model for a report created by an economic entity in machine readable form serves multiple purposes:

- **Description**: It is a clear and should be complete description of a report model (specification of what is permitted); created by standards setters or regulators or anyone else specifying a report. And obviously the clear and complete description should represent accounting and reporting rules precisely and accurately.
- **Construction**: It is a guide to the creation of a report based on that permitted report model description whereby a human can be assisted by software applications utilizing that machine readable description of permitted report models.
- **Verification**: The actual report constructed can be verified against the clear, complete description assisted by software applications utilizing that machine readable description.
- **Extraction**: Information can be effectively extracted from machine readable reports and report models assisted by software utilizing that machine readable clear and complete description.

None of this will be created by itself and stakeholders that do participate in the creation of these digital systems need to be clear as to the goal or goals these systems are to achieve.

The system should not be thought of as a "silo" of one stakeholder, rather the system is the set of all stakeholders. This graphic gives you and idea of the stakeholders related to the area of knowledge referred to as financial accounting, reporting, auditing, and analysis:



10.23. Intelligent Software Agents

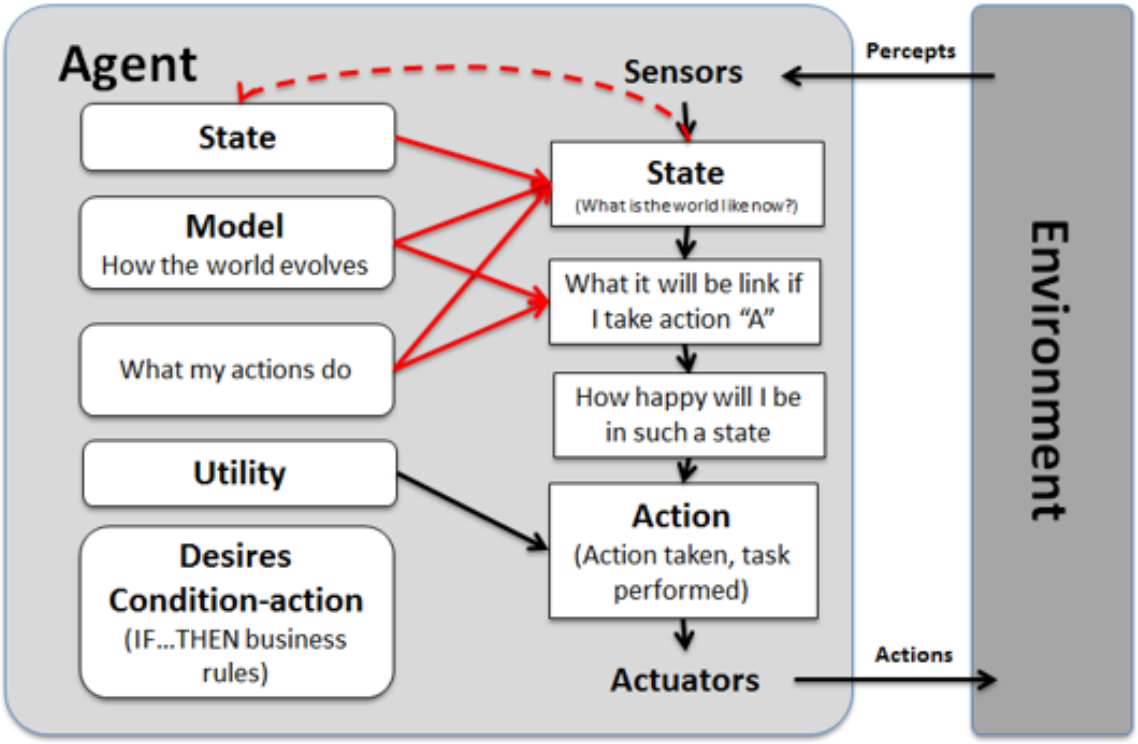
An agent is someone who acts on behalf of another. An intelligent agent is an abstract notion that links the real world agent and the notion of agency with an implementation of that functionality within software. An intelligent software agent is the abstract functionality of a system similar to a computer program; it is not the computer software program itself.

Intelligent agent[552], as we are using it, is an idea related to artificial intelligence. An intelligent agent is an autonomous entity which observes its environment through sensors and acts upon that environment using actuators in the pursuit of some goal. Russel and Norvig classified[553] intelligent agents into five groups: simple reflex agents, model-based reflex agents, goal-based agents, utility agents, and learning agents.

A utility-based agent[554] is a more sophisticated type of goal-based agent that also rates each possible scenario to see how well it achieves certain criteria with regard to production of the good outcome, therefore it is more adaptive. A utility measure is applied to the different possible actions that can be performed in the environment. The utility-based agent will rate each scenario to see how well it achieves certain

[552] Wikipedia, *Intelligent Agent*, https://en.wikipedia.org/wiki/Intelligent_agent
[553] Wikipedia, Intelligent Agent, Russel and Norvig's classification, https://en.wikipedia.org/wiki/Intelligent_agent#Russel_and_Norvig's_classification
[554] Wikipedia, *Intelligent Agents, Utility-based Agents*, retrieved August 14, 2016, https://en.wikipedia.org/wiki/Intelligent_agent#Utility-based_agents

criteria with regard to the production of a good outcome. Things like the probability of success, the resources needed to execute the scenario, the importance of the goal to be achieved, the time it will take, might all be factored in to the utility function calculations.



A utility-based agent is the same as a goal-based reflex agent but adds additional functionality of wondering what the environment will be like if a specific action is taken, evaluating if that state is desirable or undesirable given specific goals and desires given that state, and evaluating how happy the agent will be within that state. Such agents might even be allowed to change its goals.

Being able to create and configure agents to perform work takes skill and experience; as does creating the models and data that drives such intelligent software agent tools.

10.24. Contrasting and Comparing to Other Great Transmutations

To get a good understanding of the impact of the great transmutation of accounting, reporting, auditing, and analysis one can contrast and compare the impact of other great transmutations that have already occurred.

Consider the blueprint. Prior to the 1980s, drafting was done using paper and pencils. But in the 1980s CAD/CAM software was created and blueprints went digital and in subsequent years all that went even further with the introduction of BIM[555].

[555] Using Difference Between CAD/CAM and BIM to Understand How to Create Financial Reporting Expert Systems,

Other such changes have occurred with the introduction of the Universal Product Code (UPC) which saved the supply chain billions, digital photography, digital cinematography, digital music, and is now occurring for cross border trade[556].

Digital and standards will have a similar impact on financial accounting, reporting, auditing, and analysis as it has had on these other supply chains.

10.25. Starting to Get Real

The world's first standards based expert system works now and you can see it being built out[557]. You might want to keep an eye on its progress. In the United States, the Financial Data Transparency Act was signed into law[558]. To understand the possibilities, have a look at *Rise of the AiAccountants*[559].

Artificial intelligence is not going to change the world. It will be artificial intelligence combined with human intelligence that will enable change. Artificial Intelligence (AI) plus Human Intelligence (HI) will cause a transformation[560].

The Great Transmutation is underway. We have outgrown what we have but we have not created what we need to replace what we have yet. Change will be messy. If you are not sure where to start your journey into the future, I would suggest starting here

10.26. Accountancy Today and Tomorrow

They are referred to as many different names including knowledge graphs, knowledge base, graphs, networks, digital twins, mirror world, logical twins, or logical digital twin. I will use the term *logical digital twin* or professional knowledge graphs.

A *Logical Digital Twin* is a special, formal type of knowledge graph[561] or d*igital twin*[562] used by professionals. The freemasons of the information age[563] will use these tools to reconstruct how work is performed in the information age.

Effectively, a logical digital twin is a knowledge graph of logic that has a logical schema that enforces the logic of the logical digital twin to always assure that the

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[556] Cross-border Paperless Trade is Coming, https://digitalfinancialreporting.blogspot.com/2023/04/cross-border-paperless-trade-is-coming.html

[557] Charles Hoffman, CPA, *World's First Standards Based Expert System for Creating Financial Reports*, https://digitalfinancialreporting.blogspot.com/2023/01/worlds-first-standards-based-expert.html

[558] Charles Hoffman, CPA, *The Story of Our New Language*, https://digitalfinancialreporting.blogspot.com/2022/12/the-story-of-our-new-language.html

[559] Amazon.com, HITENDRA PATIL, *Rise of the AiAccountants*, https://www.amazon.com/dp/B0BTMK89BS

[560] *AI + HI = Transformation*, https://digitalfinancialreporting.blogspot.com/2023/04/ai-hi.html

[561] Wikipedia, Knowledge Graph, https://en.wikipedia.org/wiki/Knowledge_graph

[562] Digital Twin for Financial Status and Performance of Economic Entity, https://digitalfinancialreporting.blogspot.com/2023/09/digital-twin-for-financial-status-and.html

[563] Freemasons of the Information Age, https://digitalfinancialreporting.blogspot.com/2023/10/freemasons-of-information-age.html

information represented by the logical digital twin is a verifiably properly functioning logical system within the specific logical boundaries of that logical schema.

You can think of a logical digital twin as a specific point in a spectrum of knowledge graphs. A logical digital twin is a professional quality knowledge graph that is used when high quality knowledge graphs are necessary such as an XBRL-based digital financial report.

A financial report is a knowledge graph[564]. Obviously financial report knowledge graphs must be professional, high-quality knowledge graphs. I have been promoting the notion of using a logical schema[565] to enforce the logic within a financial report knowledge graph in order to maintain and prove the quality of those knowledge graphs for years. In addition to report quality, such a logical schema can enable expert system software applications to be created to process such reports (i.e. construct the report, or analyze the information contained within the report).

The examples of professional knowledge graphs used for financial reporting provide an example of what is possible with other applications of business reporting. Apparently, I have a unique approach to creating knowledge graphs[566].

For years, financial reporting teams have used countless spreadsheets and a patchwork of tools for collaboration, workflow management, project management, file transfers, approvals, and such to complete the tasks and processes required to construct financial reports. No more.

This document contains information that helps the reader to understand the moving pieces involved with having a precise and accurate understanding of the notion of knowledge graphs generally and professional quality logical digital financial reports in particular.

10.27. Audit is Broken

A Fortune article, *Wirecard shows auditing is broken. Here's why—and how to fix it*[567], points out that a September 2019 investigation by the Project on Government Oversight, a Washington, D.C., watchdog group, revealed that when the PCAOB has inspected Big Four audits, it found frighteningly high failure rates. In the most recent figures available, inspectors found Deloitte got one in 20% wrong, PwC botched 23.6%, EY screwed up 27.3%, and KPMG flopped fully 50% of the time.

Another Forbes article, *22 years after the $63 billion Enron collapse, a key audit review board finds the industry in a 'completely unacceptable' state*[568], point out; audit is out of control and the situation is "completely unacceptable" per the PCAOB.

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[564] Charles Hoffman, CPA, *Financial Report Knowledge Graph*, https://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf
[565] Charles Hoffman, CPA, *Logical Schema of Financial Report*, http://xbrlsite.com/seattlemethod/LogicalSchemaOfFinancialReports.pdf
[566] Seeing Digital Financial Reporting Differently, https://digitalfinancialreporting.blogspot.com/2023/12/seeing-digital-financial-reporting.html
[567] Fortune, *Wirecard shows auditing is broken. Here's why—and how to fix it*, https://fortune-com.cdn.ampproject.org/c/s/fortune.com/2020/06/25/wirecard-auditing-is-broken-fintech-ey-ernst-and-young/amp/
[568] Fortune, *22 years after the $63 billion Enron collapse, a key audit review board finds the industry in a 'completely unacceptable' state*, https://fortune-

CFO magazine also says audit is broken[569]. In fact, it seems hard to find someone that will tell you that audit is not broken.

What if there was a better way of audit? Engine B talks about the notion of "always-on" audit[570]. MindBridge talks about AI assisted audit[571]. The AICPA says AI is a gamechanger for audit[572].

10.28. Outdated Old School Financial Report Creation Process

The current process of creating financial reports is inefficient, error-prone, many aspects are manual, outdated, and in need of being revamped. Here is what some are saying[573]:

- **CFA Institute**: calls for "...greater efficiencies within the current inefficient system" [of creating financial reports].
- **Gartner**: "...average Fortune 1000 company used more than 800 spreadsheets to prepare its financial statements"
- **Ventana Research**: "...for larger companies, assembling the periodic external reports typically is an inefficient and error-prone process."
- **PriceWaterhouseCoopers**: "...old school manual processes..." and "commonly cut and pasted, rekeyed, or manually transferred into word processing and spreadsheet applications used for report assembly and review process steps"

The problems with spreadsheets tend to be well known and well understood[574]. Yet, accountants love their spreadsheets. Is there another way?

10.29. Today's Professional Data Janitors

Today, professional accountants, auditors, and analysts perform what amounts to data janitorial services on the data in their information systems that tend to be improperly configured and otherwise set up in a world that currently has poor semantic hygiene practices. This information systems hairball that has been glued together with spreadsheets can best be described as a kludge that can get the job done; but at what cost? The "bailing wire" and "band aids" that are used provide systems that are brittle, error prone, and all this is held together by professional accountants who tend to be overwhelmed much of the time working long hours to keep these systems running.

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com.cdn.ampproject.org/c/s/fortune.com/2023/07/26/pcaob-audit-completely-unnacceptable-error-rate-enron-big-4-consulting/amp/

[569] CFO.com, *Audits Are Broken. Here's a Radical Way to Fix Them*, https://www.cfo.com/news/audits-are-broken-heres-a-radical-way-to-fix-them/657144/

[570] Engine B, Audit Ethics, https://engineb.com/2020/11/audit-ethics-and-technology-what-is-it/

[571] MindBridge, https://try.mindbridge.ai/book-demo/

[572] AICPA, *Artificial intelligence is a game changer for auditors*, https://www.aicpa-cima.com/news/article/artificial-intelligence-is-a-game-changer-for-auditors

[573] *Old School Financial Report Creation Process*, http://xbrlsite.azurewebsites.net/2017/Library/OldSchoolProcessesIneffecient.pdf

[574] *The Problem with Spreadsheets*, https://www.youtube.com/watch?v=wbiVK6HKHHg

Those same technologies that are causing the ever-increasing volume and complexity of information that is overwhelming us is also the solution to the information overload that is being experienced.

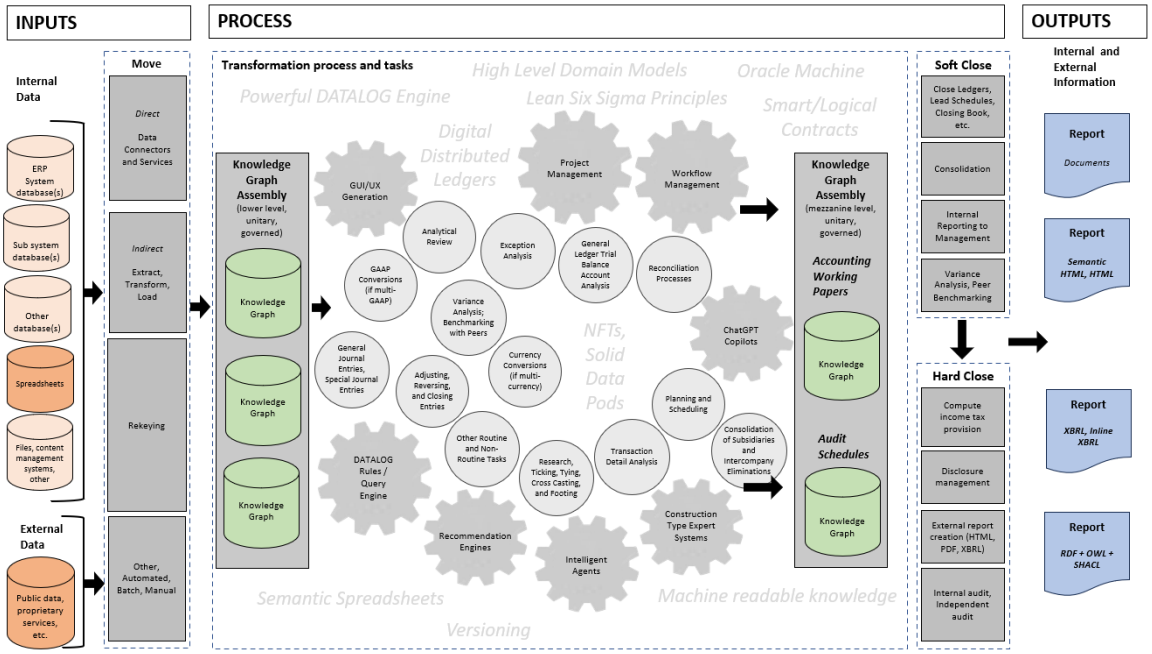
10.30. Fundamental Business Use Case

Businesses exchange information. All kinds of information. One common type of information exchanged is financial information such as the general-purpose financial report[575]. Another more general tool for exchanging information and also for the preparation of general-purpose financial reports is the electronic spreadsheet. In the past, these general-purpose financial reports and electronic spreadsheets were presentation oriented. That means while computers could read and understand how you want the information in those artifacts presented; the computer did not understand what information was provided in those artifacts or what to do with that information.

But what if a computer could understand the information contained in a general-purpose financial report or electronic spreadsheet? What if we created a new type of general-purpose financial report[576] and a new, modern type of spreadsheet[577]?

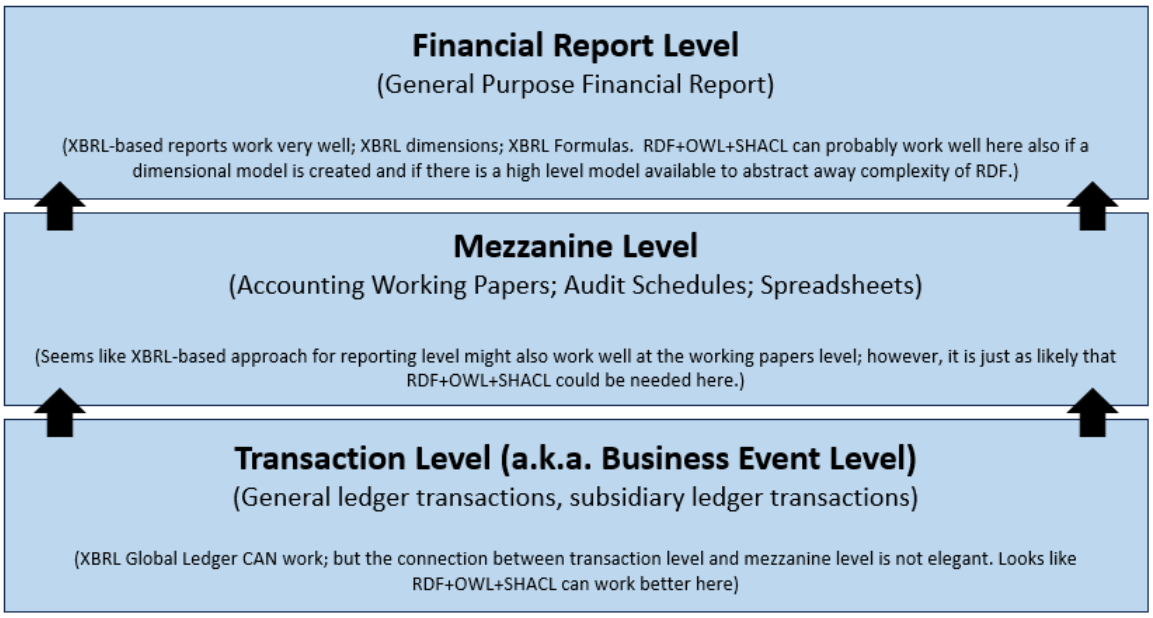
What does making general purpose financial reports and electronic spreadsheets understandable to computer software actually mean? What are the real capabilities of tools like artificial intelligence to help financial accountants, auditors, and analysts perform work? How do you apply these new technologies to get them to actually work to solve real world business problems? What new skills to you need to make this actually possible? What tasks and processes can be improved by using these new capabilities that enhance the skills of professional accountants, auditors, and analysts?

[575] General Purpose Financial Reporting Support for XBRL, https://digitalfinancialreporting.blogspot.com/2023/02/general-purpose-financial-reporting.html
[576] Universal Technology of Accountability, https://digitalfinancialreporting.blogspot.com/2023/02/universal-technology-for-accountability.html
[577] Modern Spreadsheet, https://digitalfinancialreporting.blogspot.com/2023/05/modern-spreadsheet.html



These tools do not just work for general purpose financial reports and electronic spreadsheets. These new tools enable the creation of entirely new business models and completely different paradigms for performing the tasks and processes that make up the day-to-day work that is performed by accountants, auditors, and analysts.

Considering the flow of financial and non-financial information from an enterprise resource planning (ERP) system and other systems that support the creation of the information that then ends up in the form of a general-purpose financial report. Those artifacts seem to fit into three broad categories:

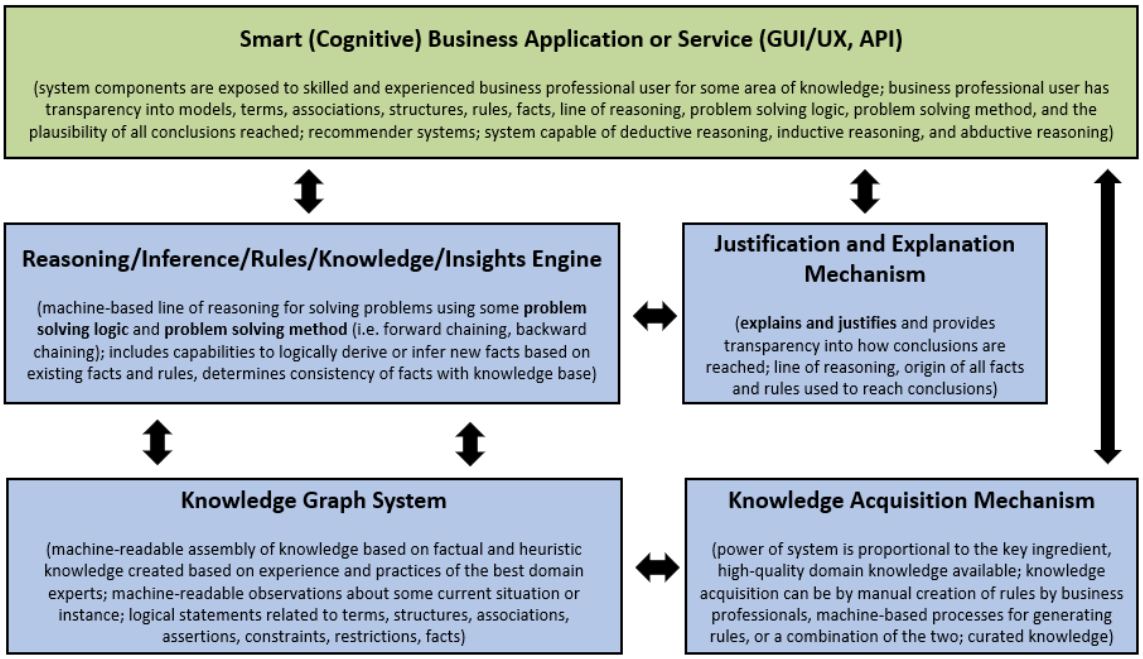


There are many technologies that are converging creating new possibilities and more modern approaches to financial accounting, reporting, auditing, and analysis[578].

10.31. Smart Systems

How much do the electronic word processing documents that you type information into or the electronic spreadsheets you use understand financial reporting, accounting, auditing, or analysis?

Well, what if they could understand? Guess what. They can. This graphic below shows the high-level components of a smart business application or service:

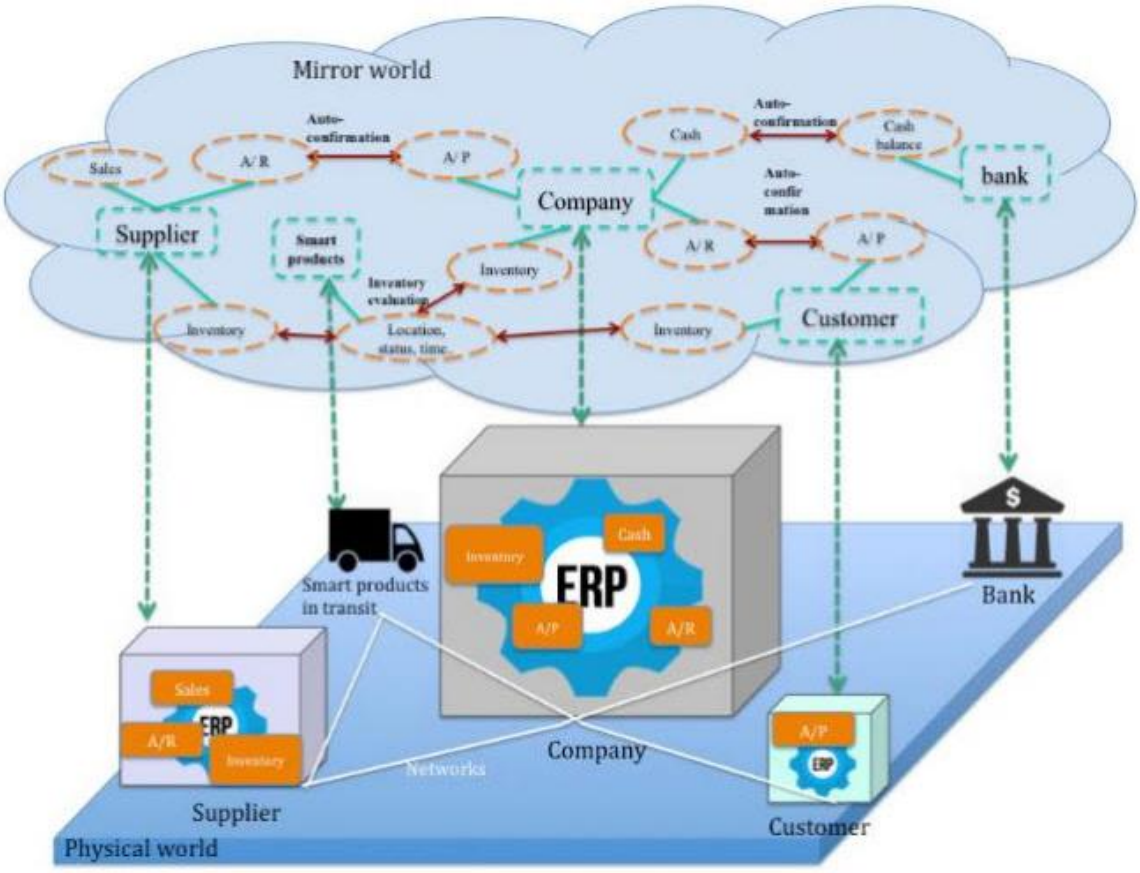


Using the proper tools provided by artificial intelligence and structured information; very reliable and useful capabilities can be created. Other capabilities can take advantage of other technologies such as machine learning, large language models (LLMs), transformers, expert systems, intelligent agents.

10.32. Digital Twins

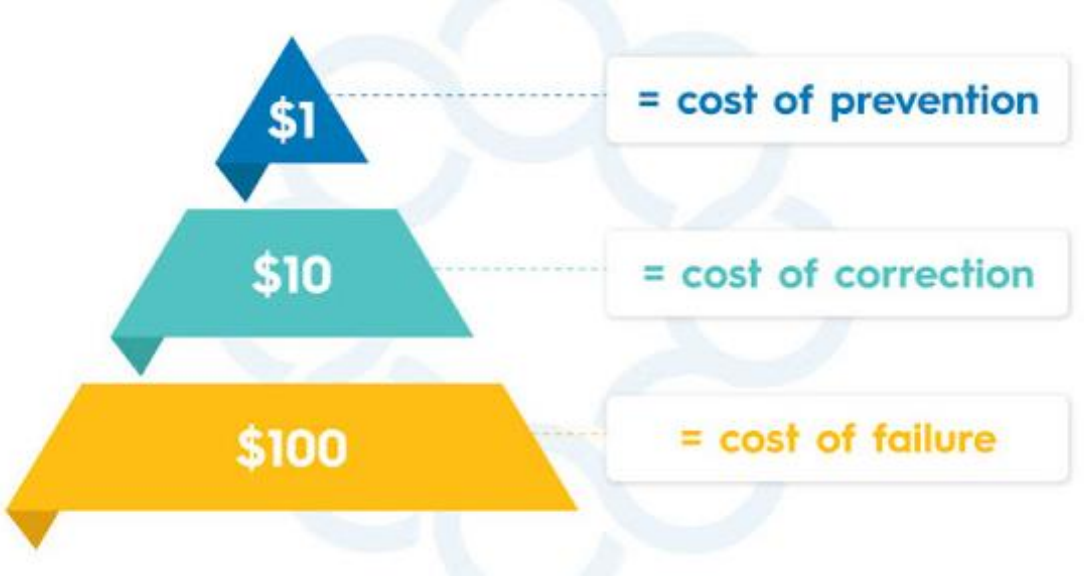
The first I have heard about the notion of a "digital twin" was in the paper, *Imagineering Audit 4.0*, written by Jun Dai and Miklos Vasarhelyi of Rutgers University[579]. In that paper they used the term "mirror world" and used that term to describe the use of technology to create machine readable virtual copy of the real world.

[578] Converging Paths to a Modern Approach to Financial Accounting, Reporting, Auditing, and Analysis, https://digitalfinancialreporting.blogspot.com/2023/09/converging-paths-to-modern-approach-to.html
[579] Jun Dai and Miklos Vasarhelyi, *Imagineering Audit 4.0*, page 10, figure 3, https://publications.aaahq.org/jeta/article-abstract/13/1/1/9242/Imagineering-Audit-4-0



One of the principles of Lean Six Sigma[580] is the 1-10-100 rule as explained by Inspectorio[581]: Comparing relative cost of preventing, correcting, and cost of errors, consider this. In relative terms, fixing a system to prevent a problem costs say $1 whereas having to correct a problem costs $10 as contrast to having to deal with the cost of the failure related to not detecting the problem is about $100.

[580] Lean Six Sigma, http://www.xbrlsite.com/mastering/Part01_Chapter02.K_LeanSixSigma.pdf
[581] Solving the Problems of the "Accidental Taxonomists" and the "Data Janitors", https://digitalfinancialreporting.blogspot.com/2024/01/solving-problems-of-accidental.html



The principles and techniques of Lean Six Sigma have been used to improve the quality of the products output by industries such as the manufacturing of automobiles and airplanes. These same ideas, principles, and techniques can be applied to financial accounting, reporting, auditing, and analysis. A first step in your journey into a new way to work, partnering with computer software applications that augment your skills, is to think about a financial report as a logical system.

Many people misinterpret the market size for XBRL-based reports because they confuse regulator mandates to submit XBRL-based reports and the real opportunity structured XBRL-based reports offer. An entirely new financial reporting paradigm is possible. This table below provides an approximate size of the market for creation of general-purpose financial reports:

Market segment	Approximate market size
Public companies financial reporting using US GAAP to SEC	About **10,000** public companies in US
Private company financial reporting in support of commercial loans to banks and others using US GAAP	About **27.9 million** private companies in US; **18,500** private companies with 500 employees or more
Not-for-profit entities financial reporting for commercial loans, federal grants using US GAAP	About **320,000** not-for-profit entities
State and local governmental entities financial reporting using governmental accounting standards; CAFR in US, IPSAS in rest of world	About **90,000** state and local governmental entities (probably similar number or double in the rest of the world)
Listed companies reporting under IFRS	About **10,000 to 30,000** globally
SMEs (small and medium size entities) reporting under IFRS	About **23 million in Europe, 40 million in China, 1.9 million in India, 2.4 Brazil** (private companies, SMEs)
Employee benefit plan annual audit reports, Department of Labor's Employee Benefits Security Administration (EBSA)	About **800,000** audited plans in US under ERISA; similar reporting in Australia, about **300,000** plans
Personal financial statements	About **1,000,000** high-net worth individuals or more

Also think about the infrastructure related to the compilation, review, or audit of such reports. Also consider internal management reporting, tax related reporting, and business reporting in general.

10.33. Fool Proof Accounting

Everyone loves sexy information dashboards that they can use to do things like manage a small business effectively. But here is the deal: if the information in that dashboard is wrong and/or not timely or is otherwise not trustworthy; then what good is the dashboard?

I am a certified public accountant (CPA) and have been doing financial accounting for about 45 years with a focus on accounting information systems. In addition, I studied and received an MBA in what was then referred to as "world class manufacturing techniques" then and is now called Lean Six Sigma.

Many small businesses (and a lot of big businesses) have problems with their reporting systems because information that is put into their systems is incorrect or incomplete. Further, the systems are not set up well which causes further struggles when you try and get information out of the system. Another problem is that descriptive metadata that helps you get information out of the system effectively is not put into the system at all or added to the system late in the process which causes problems getting information in a timely manner. Another big problem is trying to figure out where in the accounting system database information is stored so that you can get the information out of the system and put that information into a report.

The larger an organization gets, the higher the probability that multiple systems exist to store information and the systems don't talk to one another effectively. The typical solution today? Hire expensive accountants and IT people to overcome these integration problems, delay reporting so problems can be fixed, or rekey or copy/paste information, etc.

But there is a better way. Build better systems.

Remember the Lean Six Sigma principle referred to earlier as the "1-10-100 rule" that helps you understand the true cost of poor quality? For every $1 you spend to fix a system to get rid of a problem; you would spend $10 to discover errors and then fix those errors; or you would spend $100 to deal with the consequences of that mistake if the mistake is not detected and corrected.

These are the problems I see with financial accounting systems over and over and over:

1. **Inadequate account type scheme**: Accounting systems generally have a scheme for assigning a "type" to an account; basically, a method of classifying the accounts in a chart of accounts. Categories tend to be "Assets", "Liabilities", "Equity", "Income", "Expenses". Or, there may not be an account type. This is completely inadequate and causes problems. This problem tends to be caused by the design of an accounting system. Proper account types need to be used to avoid work later.
2. **Poorly set up chart of accounts**: It has been my observation that accountants are very good at working with accounting systems; but they are terrible at setting those systems up. A key to setting an accounting system

up effectively is to create a good, well-thought-out chart of accounts that help you report rather than getting in the way.

3. **Missing transaction metadata**: Critically important information that enables the proper categorization of transactions tends to be missing from accounting systems and then added later in the process, generally using spreadsheets. To understand this issue, let me point out how Workday solves this issue. Workday, an ERP system, has the notion of the "work tag"[582]. A work tag is an informal approach to adding this missing transaction metadata.
4. **Recording business event information incorrectly**: There are many reasons business event information gets recorded incorrectly, those reasons tend to fall in the following buckets: poorly trained personnel, bad mismatch of skills/experience to tasks being performed, bad accounting system design, sloppiness.
5. **Delays in fixing mistakes**: Any delay in fixing a mistake causes potential mistakes in using that information. First, systems should be fixed so mistakes are avoided. But if a mistake does occur, that mistake should be detected and fixed as soon as possible. Waiting until the end of the month or end of the year and letting the CPA fix it is not a good strategy.
6. **Avoid spreadsheets**: Spreadsheets are not a solution to a problem; they are the problem. Spreadsheets tend to be informal work-arounds.
7. **Overly manual process control mechanisms**: Process control mechanisms today tend to be overworked accounting professionals that have to manually control process quality. This manual approach is expensive, not reliable enough, and ultimately causes more important work to be delayed or simply left undone as the current, immediate crisis is addressed. The fix? Augment manual processes with automated processes and let machines help overworked humans get work done. Leverage things like Lean Six Sigma philosophies and techniques.

Fundamentally, don't fight symptoms; solve the problem that is causing the symptom. This can be hard at times but the proper investments in the right areas will pay dividends in the long term. Financial reporting is a manufacturing or construction process. What is manufactured/constructed is the information.

Fool proof accounting results in good reporting. Without very good reporting, it is impossible to really have algorithmic regulation.

10.34. Algorithmic Regulation

The document *The Great Transmutation*[583] discusses the changes that are occurring and the notion that many call algorithmic regulation. People refer to this paradigm shift in different ways. Here are how some people package this paradigm shift:

- MIT refers to this as **Algorithmic Business Thinking**[584]

[582] Workday, Tales of the Cloud: The Story of Worktags, https://blog.workday.com/en-us/2012/tales-of-the-cloud-the-story-of-worktags.html
[583] Charles Hoffman, CPA, *The Great Transmutation*, http://xbrlsite.azurewebsites.net/2022/Library/TheGreatTransmutation.pdf

- Carnegie Mellon University refers to this as **Computational Thinking**[585]
- Harvard University refers to this as **Regulation, the Internet Way**[586]
- Vanderbilt University refers to this as **Regulation 2.0**[587]
- The Data Coalition calls this **Smart regulation**[588]
- Tim O'Reilly Founder and CEO O'Reilly Media Inc. calls it **Algorithmic regulation**[589]
- Deloitte refers to this as "**The Finance Factory**" and **Digital Finance**[590]
- Robert Kugel of Ventana Research calls it "**Digital Finance**"[591]
- The government of Norway calls this "**Nordic Smart Government and Business**"[592]

10.35. Creation of a New Cottage Industry

Logical digital twins could be, and I predict will be, the foundation of a new cottage industry. That cottage industry will reorganize how financial accounting, reporting, auditing, and analysis work tasks and processes will be performed. Rather than dealing with the symptoms of the problem; logical digital twins will help solve the problem and the symptoms will go away. In this current system; accountants, auditors, and analysts are effectively working as data janitors fixing data quality problems, dealing with the aftermath of the problems. There is far too much "copy", "paste", "adjust" (CPA) involved in the work today. Tomorrow, skilled experienced professionals will work side-by-side with smart computer-based systems.

Think modern semantic spreadsheets[593], semantic accounting working papers and audit schedules[594] rather than presentation-oriented Excel spreadsheets, digital XBRL-based financial reports[595] as contrast to their presentation-oriented

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[584] MIT, Accelerating Digital Transformation with Algorithmic Business Thinking, https://executive.mit.edu/course/accelerating-digital-transformation-with-algorithmic-business-thinking/a056g00000URaaQAAT.html
[585] Carnegie Mellon Center for Computational Thinking, https://www.cs.cmu.edu/~CompThink/
[586] Harvard University, Regulation, the Internet Way, https://datasmart.ash.harvard.edu/news/article/white-paper-regulation-the-internet-way-660
[587] SSRN, *Regulation 2.0: The Marriage of New Governance and Lex Informatica*, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2746229
[588] Smart Regulation, http://xbrl.squarespace.com/journal/2012/11/12/smart-regulation-graphic-shows-the-big-picture.html
[589] Tim O'Reilly Founder and CEO O'Reilly Media Inc., Open Data and Algorithmic Regulation, https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/
[590] Deloitte, *Finance 2025: Digital transformation in finance*
Our eight predictions about digital technology for CFOs, https://www2.deloitte.com/us/en/pages/finance-transformation/articles/finance-digital-transformation-for-cfos.html
[591] Robert Kugel, *The Rising Expectations for Finance Analytics*, https://www.linkedin.com/pulse/rising-expectations-finance-analytics-robert-kugel/
[592] Nordic Smart Government and Business, https://nordicsmartgovernment.org/
[593] Modern Spreadsheet, https://digitalfinancialreporting.blogspot.com/2023/05/modern-spreadsheet.html
[594] Semantic Accounting and Auditing Working Papers, https://digitalfinancialreporting.blogspot.com/2023/05/semantic-accounting-and-auditing.html
[595] General Purpose Financial Reporting Support for XBRL, https://digitalfinancialreporting.blogspot.com/2023/02/general-purpose-financial-reporting.html

counterparts. Think intelligent software agents. Think reliable rules-based expert systems that are then supplemented by machine learning, transformers, LLMs, and copilots[596]. Think digital distributed ledgers. Think logical system.

[596] Useful Generative AI Coming to Accounting and Reporting, https://digitalfinancialreporting.blogspot.com/2023/11/useful-generative-ai-coming-to.html