1. The Great Transmutation

> "If I had asked people what they wanted, they would have said faster horses." (*Henry Ford*)

We are arguably in the midst of ***The Great Transmutation*** that is changing the world of financial accounting, reporting, auditing, and analysis 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[1]". Another definition of transmutation is "an act that changes the form or character or substance of something[2]".

It is not like accounting has not changed or been changed before. Accounting has changed before in many ways[3]. Jane Gleeson-White titled chapter 1 of her book, *Double Entry: How the Merchants of Venice Created Modern Finance*[4]; **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.

1.1. 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[5].

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*[6].

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[1] Google, *Transmutation*, https://www.google.com/search?q=transmutation+definition&oq=transmutation

[2] Vocabulary.com, *Transmutation*, https://www.vocabulary.com/dictionary/transmutation

[3] Accounting Timeline, http://xbrlsite.azurewebsites.net/2021/library/AccountingTimeline.jpg

[4] Amazon.com, Jane Gleeson-White, *Double Entry: How the Merchants of Venice Created Modern Finance*, page 10, https://www.amazon.com/gp/product/B007Q6XKA8/

[5] Google Books, Arthur Levine and Scott van Pelt, *The Great Upheaval*, https://www.google.com/books/edition/The_Great_Upheaval/Y5U9EAAAQBAJ

[6] Bigthink, Peter Leyden, *The Great Progression 2025 - 2050*, https://bigthink.com/progress/the-great-progression-peter-leyden/

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> "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:

- 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.

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***[7] 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.

1.2. 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[8] 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.

1.3. 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

[7] *Universal Digital Financial Reporting Framework*, http://accounting.auditchain.finance/library/UniversalDigitalFinancialReportingFramework.pdf

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

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and Exchange Commission (SEC) began standardizing the jargon of accounting and reporting into what has become United States Generally Accepted Accounting Principles[9] (US GAAP) in Regulation S-X[10].

Another big step in the transmutation was in 1975 when what became International Financial Reporting Standards[11] (IFRS) was created[12] 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 by machines based processes.

1.4. Knowledge based systems

Knowledge representation[13] 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.

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.

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[9] CFA Institute, *US GAAP: Generally Accepted Accounting Principles*, https://www.cfainstitute.org/en/advocacy/issues/gaap#sort=%40pubbrowsedate%20descending

[10] 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

[11] CFA Institute, IFRS: International Financial Reporting Standards, https://www.cfainstitute.org/advocacy/issues/international-finance-reporting-stds

[12] Deloitte, Preface to International Financial Reporting Standards, https://www.iasplus.com/en/projects/completed/other/project89

[13] 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

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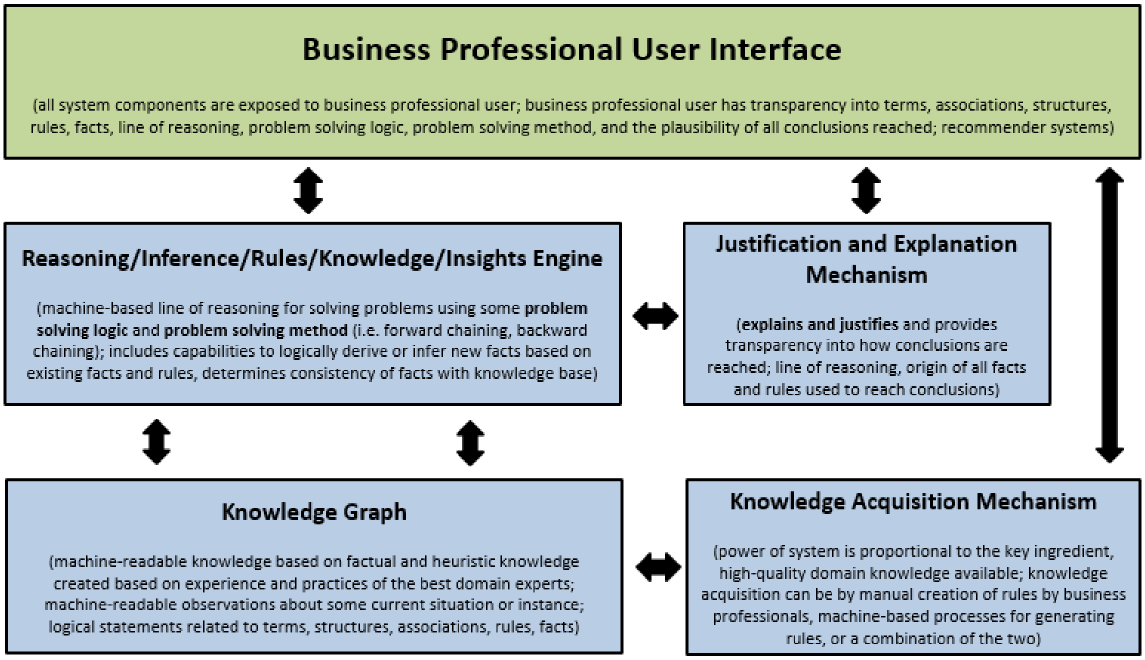
These systems are commonly referred to as knowledge based systems. The following graphic shows the components of a knowledge based system:



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.

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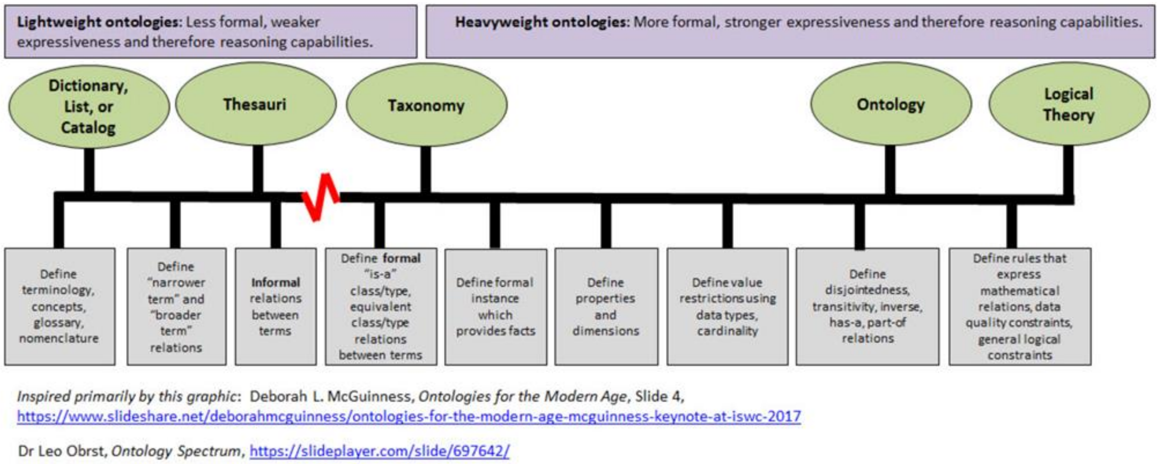
1.5. Expressing Knowledge in Machine Readable Form

The graphic below[14] 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.



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[15].

But all this boils down to expressing the most logic possible as formally as possible as to maximize understandability which will maximize the 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 from catastrophic failures caused by things like logical paradoxes or infinite loops.

1.6. 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[16].

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[14] Ontology Spectrum, http://xbrlsite.azurewebsites.net/2019/Library/OntologySpectrum.jpg

[15] Wikipedia, *Logical Connective*, https://en.wikipedia.org/wiki/Logical_connective

[16] Charles Hoffman, CPA, *Logic and Knowledge Graphs*, http://www.xbrlsite.com/mastering/Part02_Chapter05.A1_LogicAndKnowledgeGraphs.pdf

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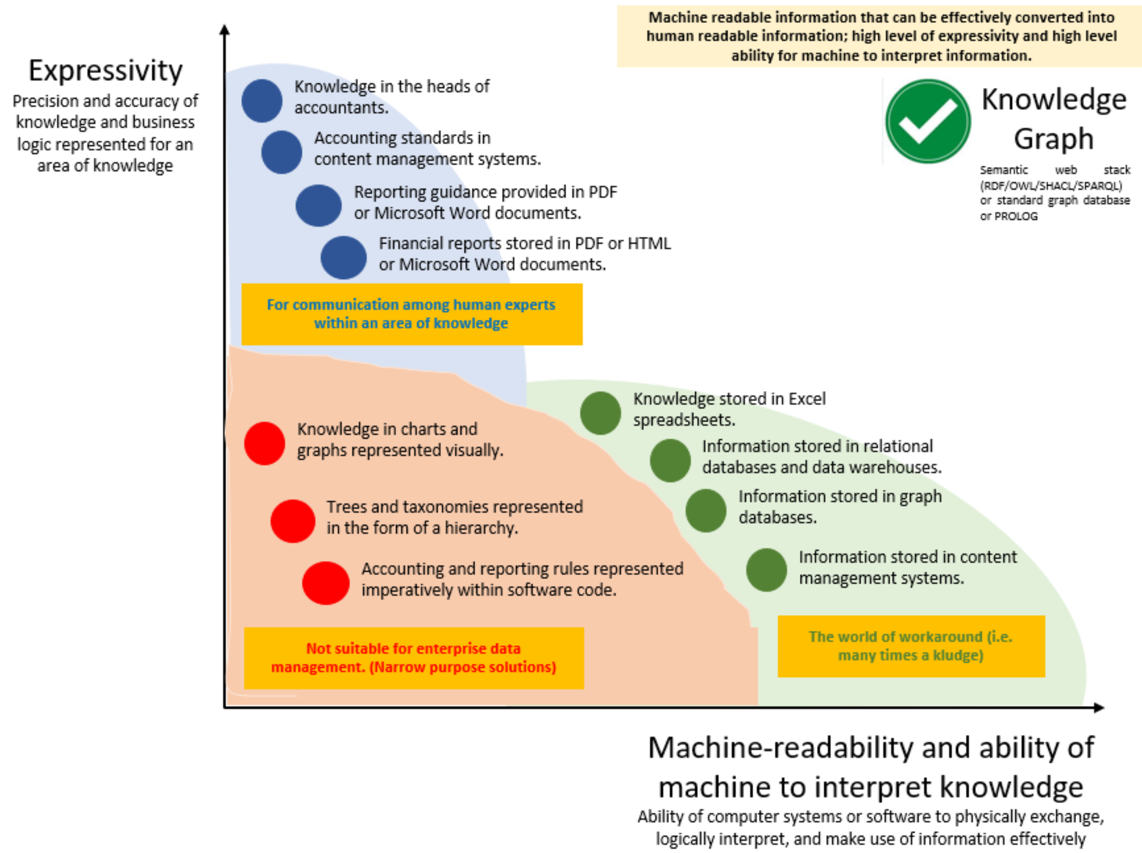
1.7. Digitizing the Knowledge in the Heads of Accountants

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*[17]; 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:



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.

1.8. 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 and 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.

[17] 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

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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.

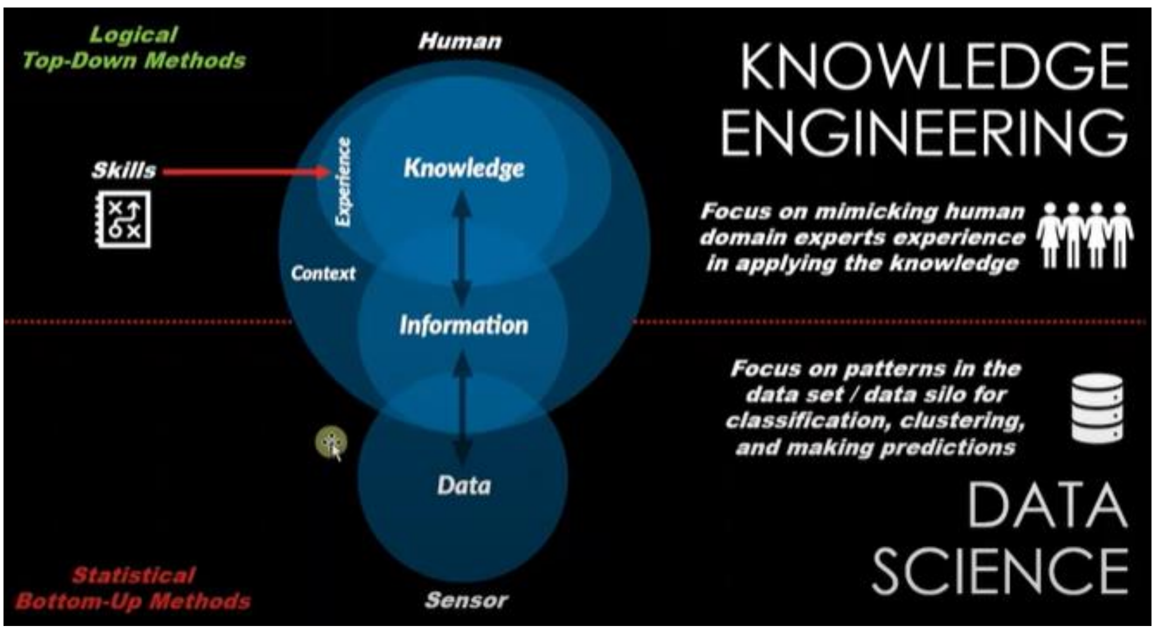
So how exactly will all this knowledge in the heads of accountants be converted into machine-readable form? There are three fundamental approaches:

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.

Doing this right is like taking a raw material like a barrel of crude oil and refining it into high-octane racing fuel[18].

This graphic below helps one understand how knowledge acquisition can be achieved[19]:



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

[18] Understanding the Power of Classification, http://xbrl.squarespace.com/journal/2019/5/14/understanding-the-power-of-classification.html

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

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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[20].

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.

1.9. Differentiating the Two Types of Artificial Intelligence

There are two approaches to implementing artificial intelligence and the right approach should be used for the given job[21]. 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[22])
    - **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

You can combine both approaches and create a third approach which is a hybrid of both approaches. Each approach has its pros and cons.

[20] Understanding the Law of Conservation of Complexity, http://xbrl.squarespace.com/journal/2015/5/24/understanding-the-law-of-conservation-of-complexity.html

[21] *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

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

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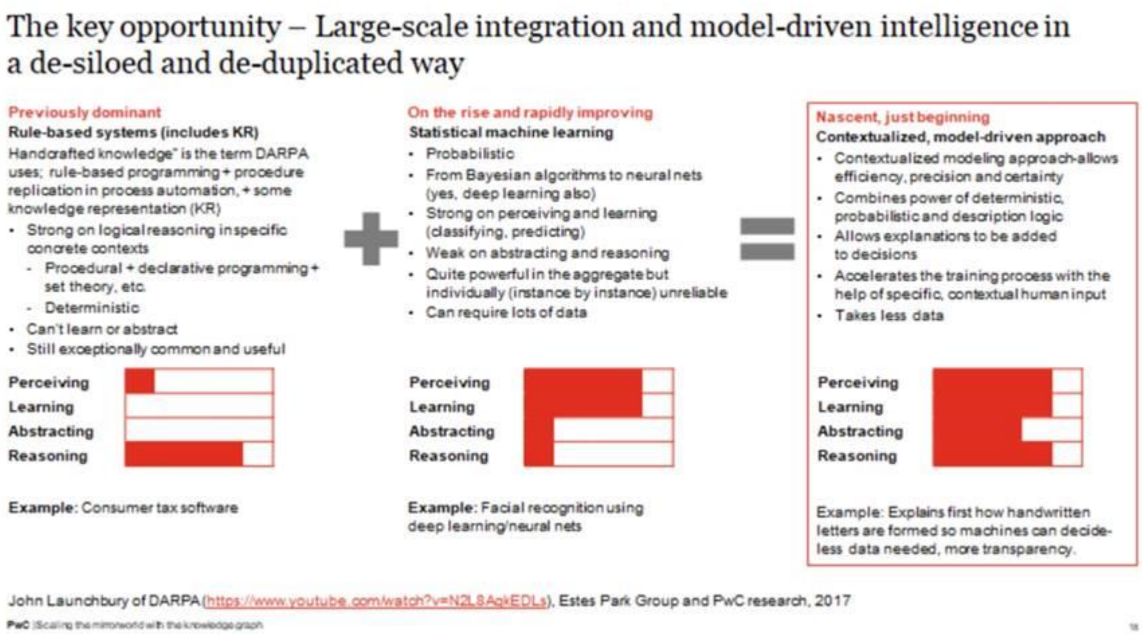
DARPA and PWC do an excellent job of explaining the capabilities of artificial intelligence. This presentation[23], video[24] and this article[25] provide a summary worth reading.

1.10. 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*?[26] 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:



Both over estimating and under estimating the capabilities of artificial intelligence have negative consequences. *The AI Ladder*[27], 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.

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[23] DARPA, *A DARPA Perspective on Artificial Intelligence*, https://www.darpa.mil/attachments/AIFull.pdf

[24] YouTube.com, *A DARPA Perspective on Artificial Intelligence*, https://youtu.be/-O01G3tSYpU

[25] 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

[26] 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

[27] O'Reilly Media, Rob Thomas, *The AI Ladder*, https://www.oreilly.com/online-learning/report/The-AI-Ladder.pdf

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- **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*[28] 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 and auditors. But artificial intelligence must make things better, faster, and/or cheaper to be useful.

Accounting, reporting, auditing, and analysis cannot be a black box. Explainable AI (XAI)[29] 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.

1.11. 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[30]. 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.

[28] 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

[29] ACCA, *Explainable AI: Putting the user at the core*, https://www.accaglobal.com/uk/en/professional-insights/technology/Explainable_AI.html

[30] Implementing Knowledge Graphs, http://xbrl.squarespace.com/journal/2021/9/20/implementing-knowledge-graphs.html

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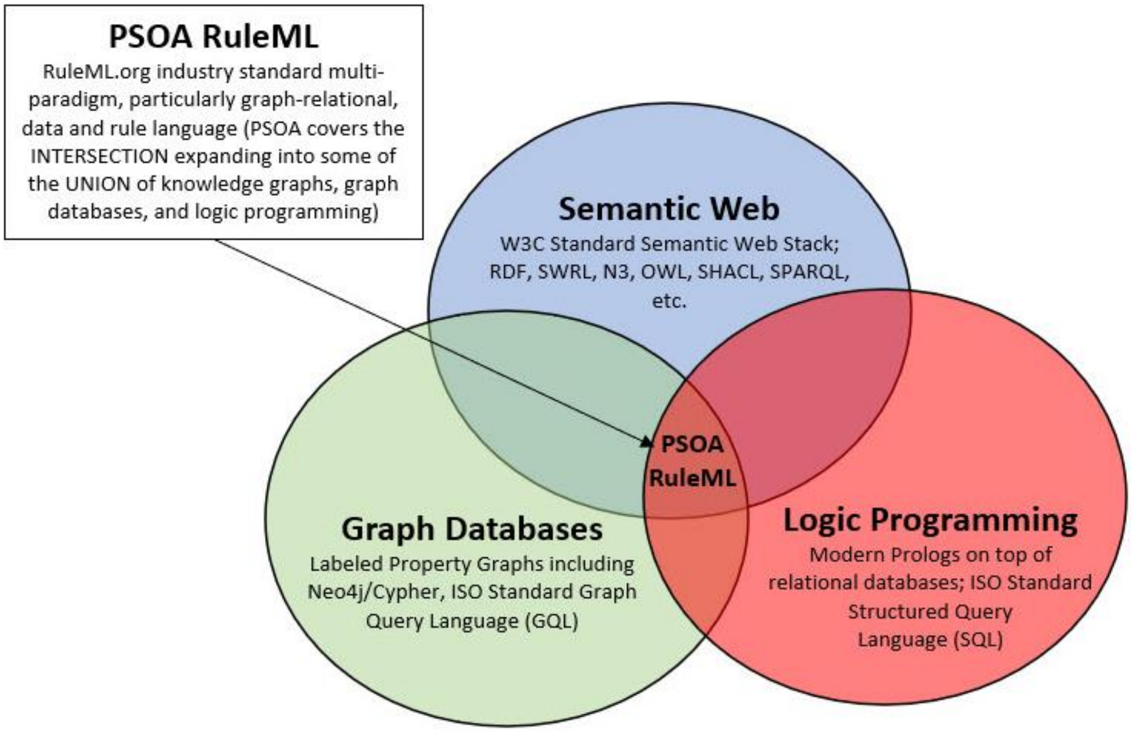
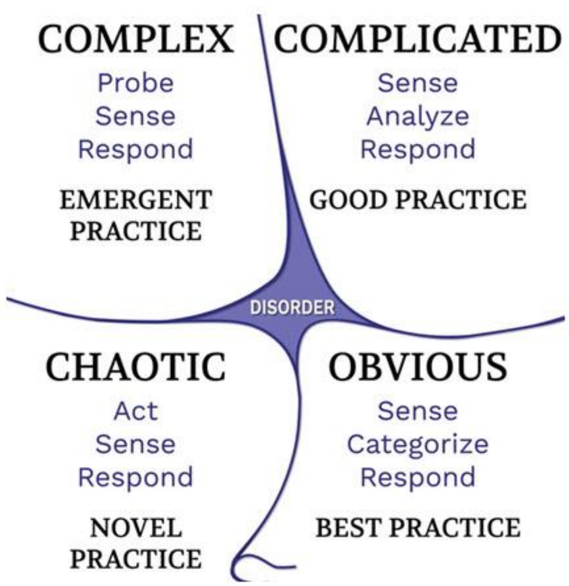


1.12. Sensemaking

Financial accounting, reporting, auditing, and analysis is an area of knowledge. Sensemaking[31] 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[32] is a model for performing sensemaking.



[31] Sensemaking, http://xbrl.squarespace.com/journal/2021/11/18/sensemaking.html

[32] YouTube.com, *The Cynefin Framework*, https://www.youtube.com/watch?v=N7oz366X0-8

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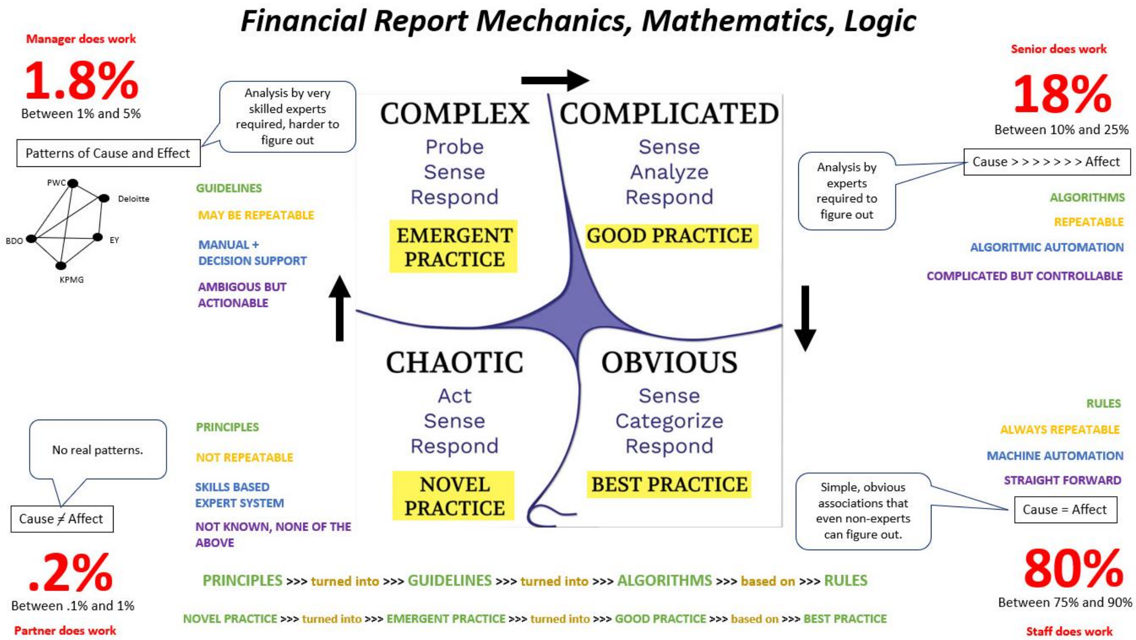
Applying the Cynefin Framework to the area of knowledge of accounting, reporting, auditing, and analysis helps one understand that knowledge can be put into machine readable form.



The bottom line is that more knowledge can be put into 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.

1.13. 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.

1.14. Logical Theory Describing Financial Report

A financial report can be thought of as a knowledge graph[33]. 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:

[33] Financial Report Knowledge Graph, http://xbrlsite.azurewebsites.net/2021/Library/FinancialReportKnowledgeGraphs.pdf

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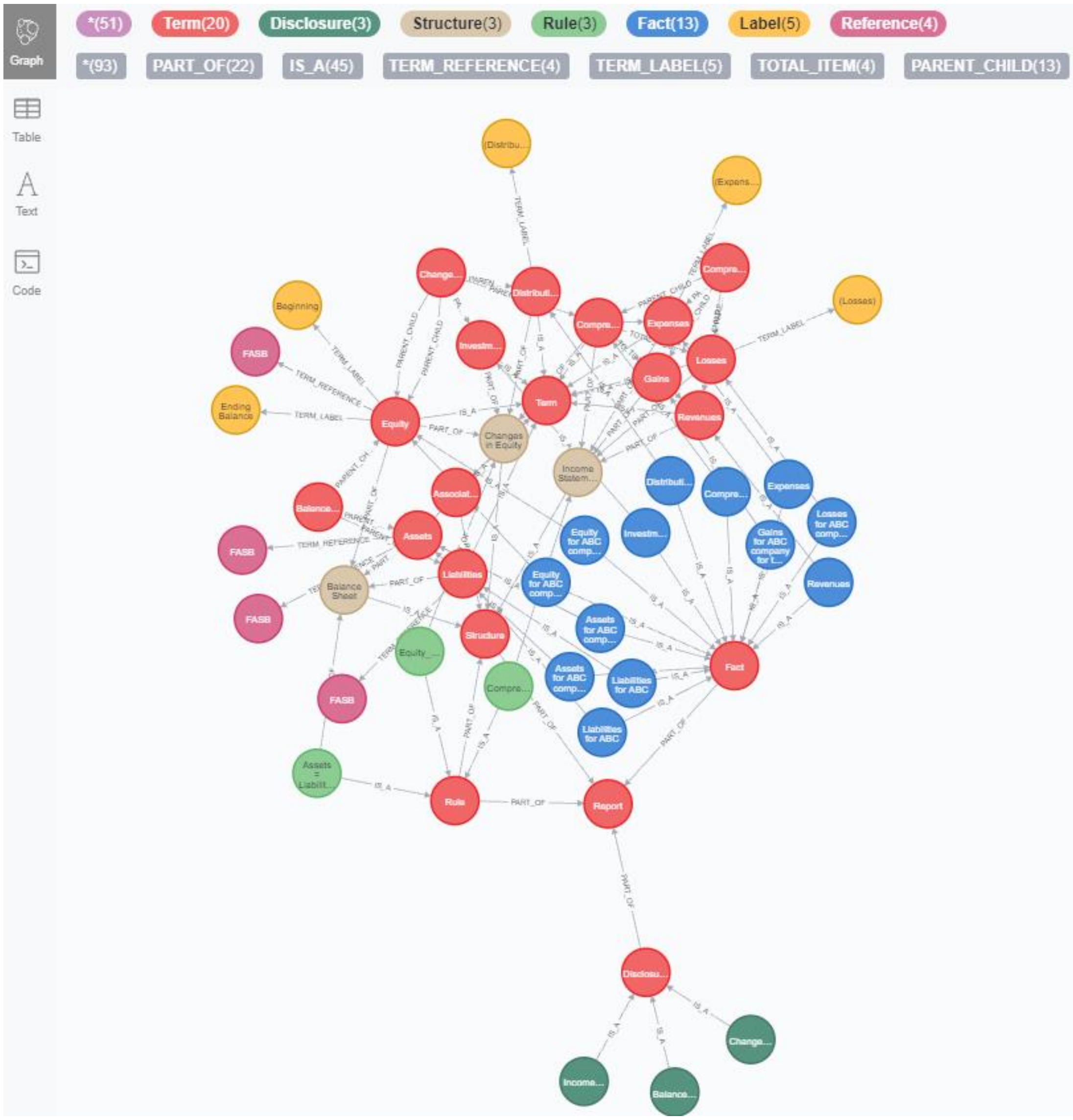
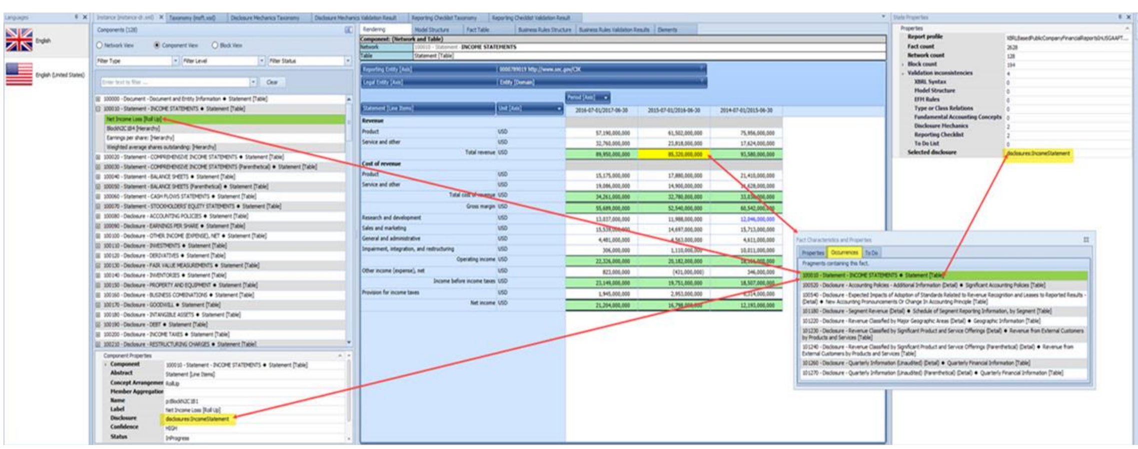


And the same information might look like this for a human to make use of:



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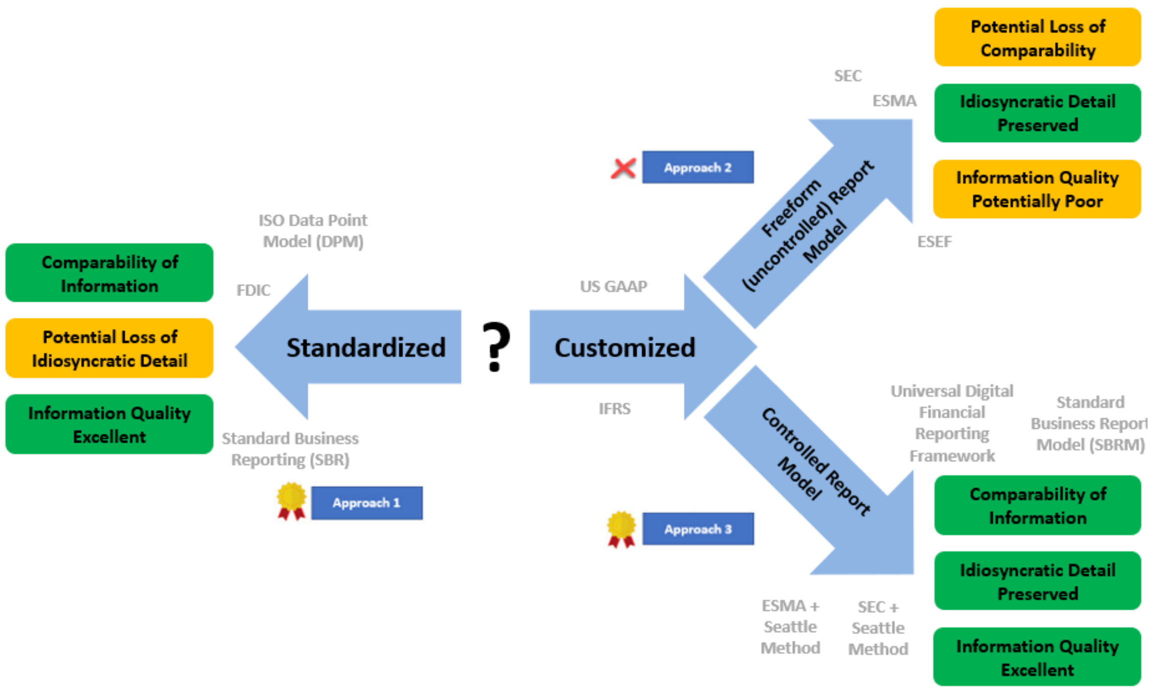
1.15. Control and Flexibility

US GAAP and IFRS based financial reports are not forms. The *Seattle Method*[34] is an approach to managing flexibility. The *Seattle Method* is a proven, 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.



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***

[34] *Seattle Method*, http://xbrlsite.com/seattlemethod/SeattleMethod.pdf

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- 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)

1.16. Properly Functioning Logical System

In her book *An Introduction to Ontology Engineering*[35], C. Maria Keet, PhD, provides 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:

- **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.

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

[35] C. Maria Keet, PhD, *An Introduction to Ontology Engineering*, PDF page 23, https://people.cs.uct.ac.za/~mkeet/files/OEbook.pdf#page=23

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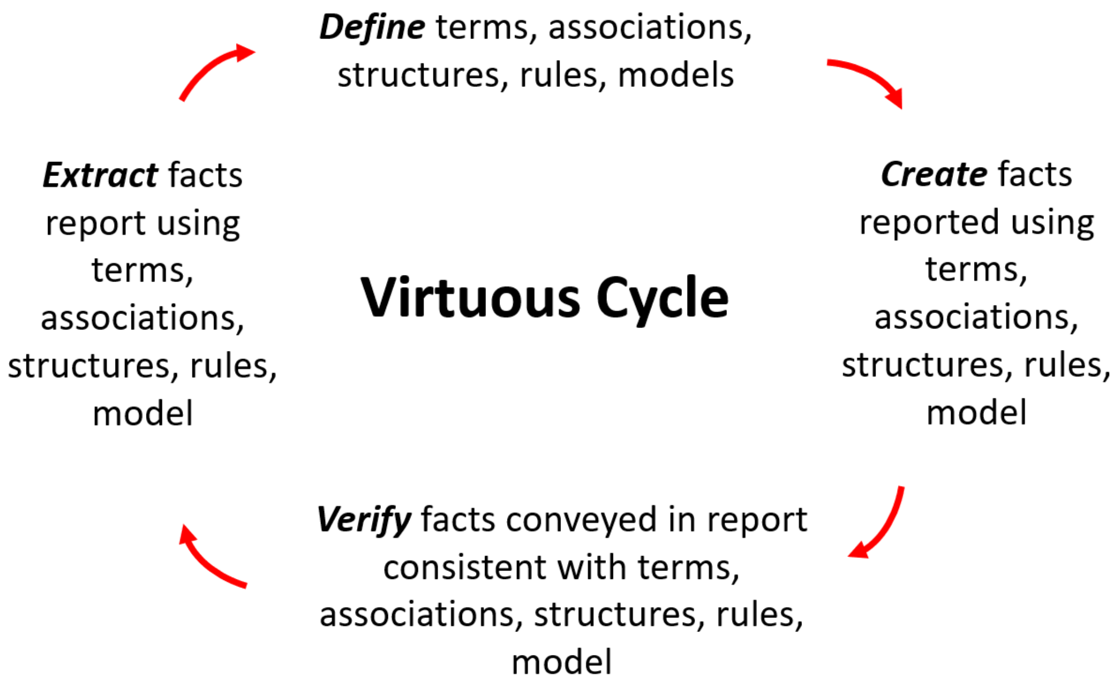
logical system is properly functioning, it creates a virtuous cycle[36]. This cycle is controlled using the complete set of rules.



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*[37].

1.17. 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[38] 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). Theories describe patterns. (see the ontology spectrum[39])

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[36] Charles Hoffman, CPA, *Virtuous Cycle*, http://xbrl.squarespace.com/journal/2020/4/29/virtuous-cycle.html

[37] Charles Hoffman, CPA, *Logical Systems*, http://www.xbrlsite.com/mastering/Part02_Chapter05.A_LogicalSystems.pdf

[38] Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory

[39] *Difference between Taxonomy, Conceptual Model, Logical Theory*, http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html

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- **Proof theory**: The ideas of proof theory[40] can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems using mathematics[41]. 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[42] is preferable to general model theory. Models provide flexibility.
- **Set theory**: Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory[43] is preferred to naïve set theory.
- **Graph theory**: Directed acyclic labeled property graphs[44] 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[45] is a subset of first-order logic and is the basis for Prolog[46]. Datalog[47] 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).
- **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**[48] (used by relational databases) is preferred to the open world assumption which can have decidability issues;
    - **negation as failure**[49] (used by relational databases) should be explicitly stated;
    - **unique name assumption**[50] (used by relational databases) should be explicitly stated;
- **Dimensional fact model**: The dimensional fact model[51] provides a clear and exhaustive representation of multidimensional concepts. XBRL Dimensions specifies a dimensional fact model.

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40 Stanford University, *The Development of Proof Theory*, *The Aims of Proof Theory*, https://plato.stanford.edu/entries/proof-theory-development/#AimProThe
41 Samuel R. Buss, *An Introduction to Proof Theory*, https://math.ucsd.edu/~sbuss/ResearchWeb/handbookI/ChapterI.pdf
42 Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory
43 Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory
44 Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph
45 Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause
46 Wikipedia, *Prolog*, https://en.wikipedia.org/wiki/Prolog
47 Wikipedia, *Datalog*, https://en.wikipedia.org/wiki/Datalog
48 Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption
49 Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure
50 Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption
51 Wikipedia, Dimensional Fact Model, https://en.wikipedia.org/wiki/Dimensional_fact_model

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- **Logical Theory Describing Financial Report**: The *Logical Theory Describing Financial Report*[52] is a logical conceptualization of the mechanical, mathematical, structural, and 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)[53] 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)[54] 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.

1.18. Why is this Important?

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**[55]
- Carnegie Mellon University refers to this as **Computational Thinking**[56]
- The Data Coalition calls this **Smart regulation**[57]
- Tim O'Reilly Founder and CEO O'Reilly Media Inc. calls it **Algorithmic regulation**[58]
- Deloitte refers to this as "**The Finance Factory**" and **Digital Finance**[59]
- Robert Kugel of Ventana Research calls it "**Digital Finance**"[60]

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[52] Charles Hoffman, CPA, *Logical Theory Describing Financial Report (Terse)*, http://xbrlsite.com/seattlemethod/LogicalTheoryDescribingFinancialReport_Terse.pdf

[53] OMG, *Standard Business Report Model (SBRM)*, https://www.omg.org/intro/SBRM.pdf

[54] XBRL International, XBRL Essentials, https://specifications.xbrl.org/xbrl-essentials.html

[55] MIT, Accelerating Digital Transformation with Algorithmic Business Thinking, https://executive.mit.edu/course/accelerating-digital-transformation-with-algorithmic-business-thinking/a056g00000URaaQAAT.html

[56] Carnegie Mellon Center for Computational Thinking, https://www.cs.cmu.edu/~CompThink/

[57] Smart Regulation, http://xbrl.squarespace.com/journal/2012/11/12/smart-regulation-graphic-shows-the-big-picture.html

[58] 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/

[59] 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

[60] Robert Kugel, *The Rising Expectations for Finance Analytics*, https://www.linkedin.com/pulse/rising-expectations-finance-analytics-robert-kugel/

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- The government of Norway calls this "**Nordic Smart Government and Business**"[61]
- I refer to all this as **Computational Professional Services**[62]. (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[63]. 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 are 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. Using the appropriate map, such as a map of New York City, would work better.

1.19. 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.

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[61] Nordic Smart Government and Business, https://nordicsmartgovernment.org/

[62] Computational Professional Services, http://www.xbrlsite.com/mastering/Part00_Chapter01.A1_ComputationalProfessionalServices.pdf

[63] Data Science Central, Kurt Cagle, *From Knowledge Graphs To Knowledge Portals*, https://www.datasciencecentral.com/from-knowledge-graphs-to-knowledge-portals/

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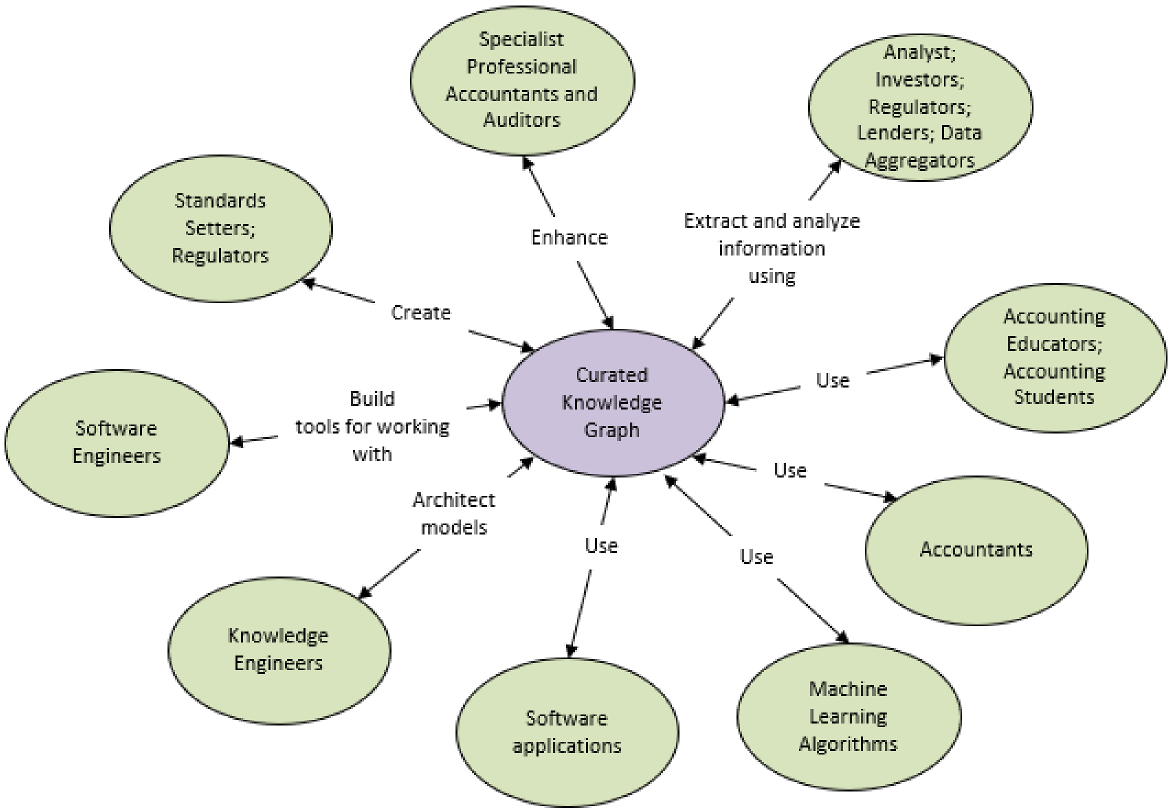

1.20. Intelligent Software Agents

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[64], 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[65] intelligent agents into five groups: simple reflex agents, model-based reflex agents, goal-based agents, utility agents, and learning agents.

A utility-based agent[66] 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

[64] Wikipedia, *Intelligent Agent*, https://en.wikipedia.org/wiki/Intelligent_agent

[65] Wikipedia, *Intelligent Agent*, Russel and Norvig's classification, https://en.wikipedia.org/wiki/Intelligent_agent#Russel_and_Norvig's_classification

[66] Wikipedia, *Intelligent Agents, Utility-based Agents*, retrieved August 14, 2016, https://en.wikipedia.org/wiki/Intelligent_agent#Utility-based_agents

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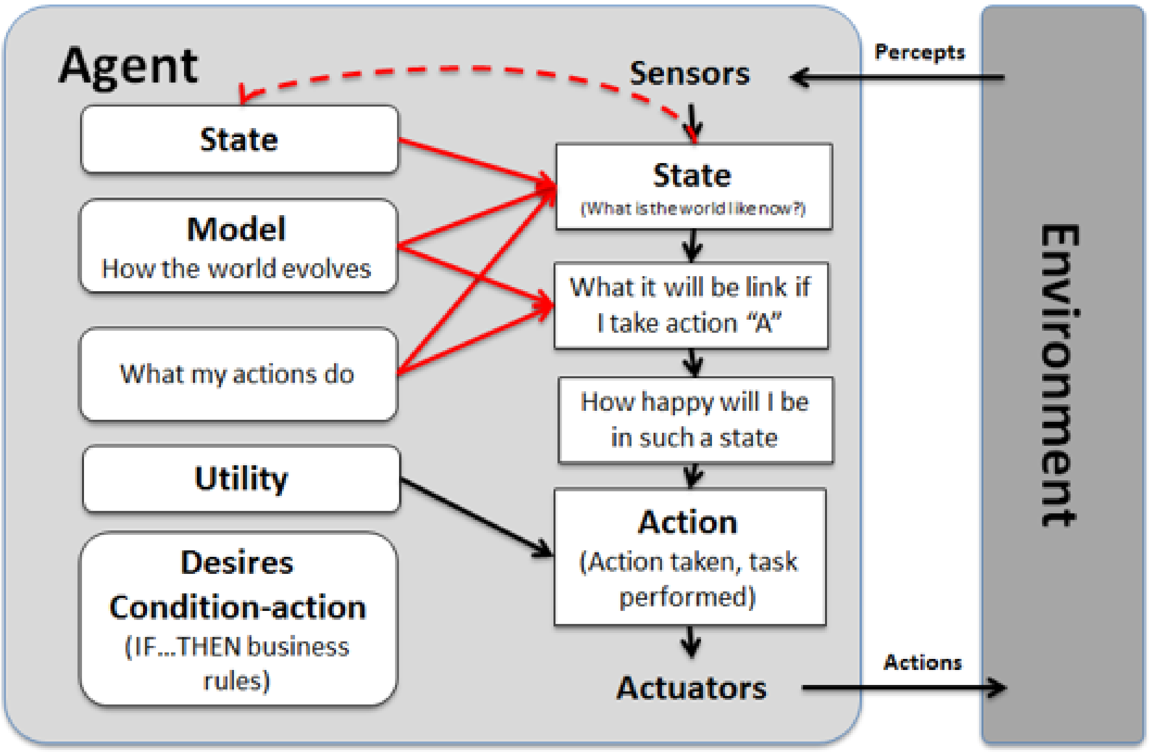
utility-based agent will rate each scenario to see how well it achieves certain criteria with regard to the production of a good outcome. Things like the probability of success, the resources needed to execute the scenario, the importance of the goal to be achieved, the time it will take, might all be 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.

1.21. Get Started

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 on my blog, *The End (Start Here)*[67].

[67] *The End (Start Here)*, http://xbrl.squarespace.com/journal/2022/4/4/the-end-start-here.html

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