Artificial Intelligence and Knowledge Engineering Basics in a Nutshell

A nontechnical introduction to technology that will shape your future for professional accountants and other business professionals

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

Executive summary:

- 81% of business leaders do not understand artificial intelligence[1]. Yet, PWC predicts that AI is going to drive a $15.7 trillion increase in GDP, a 14% increase which makes it the biggest commercial opportunity that exists today[2]. PWC is investing $3 billion to upskill their employees to address the current mismatch between existing skills and what is needed in our new digital environment[3].
- Changes that will be brought about by what is being called "the artificial intelligence revolution" among other terms will unquestionably be significant. It is not useful to overstate or understate the impact[4].
- The key to surviving and thriving during the artificial intelligence revolution and in its aftermath is understanding how computers work and knowledge engineering.
- Computers work per the rules of mathematics. Mathematics works per the rules of logic. The primary gap that needs to be filled is for professional accountants and business professionals is to gain a sound understanding of how computers actually work and the skills necessary to leverage these very useful tools of accounting, reporting, auditing, and analysis in a digital environment appropriately.
- Business professionals have an innate understanding of logic. All that they need to do is to supplement this informal natural understanding of logic into a slightly more formal understanding which will enable business professionals to have effective conversations with technical professionals related to employing technology to perform work.

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[1] *The AI Ladder*, http://xbrl.squarespace.com/journal/2019/10/19/the-ai-ladder.html
[2] PWC, *AI to drive GDP gains of $15.7 trillion with productivity, personalisation improvements*, https://www.pwc.com/gx/en/news-room/press-releases/2017/ai-to-drive-gdp-gains-of-15_7-trillion-with-productivity-personalisation-improvements.html
[3] *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
[4] Charles Hoffman, *Getting Ready for the Digital Age of Accounting, Reporting and Auditing: a Guide for Professional Accountants*, http://xbrlsite.azurewebsites.net/2017/Library/GettingReadyForTheDigitalAgeOfAccounting.pdf

Computers seem to perform magic. How computers do what they do tends to be a mystery to many people. But computers are really simply machines that follow very specific instructions to get work done. Skilled craftsmen who wield their tools effectively which includes providing the appropriate machine-readable instructions enable these machines to perform in mysterious ways and provide the users of these tools with what seems to be magic.

Psychology Today defines empathy[5] as "the experience of understanding another person's condition from their perspective". Borrowing from that definition and modifying it slightly, think of c**omputer empathy** as the experience of understanding how computer software works from the perspective of the computer. Computer empathy is about understanding how a computer works so that you can better understand that tool and how to employ that tool in your craft to perform useful work reliably, repeatedly, predictably, and safely.

Computer empathy is about demystifying accounting, reporting, auditing, and analysis in a digital environment. No magic; no metaphysics. Engineering.

This document provides a framework and principles to think about computers in a deliberate and conscious manner.

Another term for this is *computational thinking*[6]. **Computational thinking** is a thought process involved in formulating problems and their solutions so that the solutions are represented in a logical, clear, and systematic form that can be explained to and effectively carried out by a computer or human.

Engineering is the application of a systematic, disciplined, quantifiable, methodical, rigorous approach to the development, operation, and maintenance of something. 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. This document helps those that choose to be master craftsmen and desire to harness the power of the computers in the performance of their craft.

Adapting to Changes Caused by Artificial Intelligence

The impact artificial intelligence will have on accounting, auditing, reporting, and analysis should not be understated[7]. It should not be overstated either. Humans collaborating with

[5] Psychology Today, *Empathy Basics*, https://www.psychologytoday.com/basics/empathy

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

[7] PBS, Frontline, *In the Age of AI*, https://www.pbs.org/video/in-the-age-of-ai-zwfwzb/

machines to perform work empowered, even supercharged, by machine-readable information represented by ontology-like things will drive an evolution in software over the coming years. Another way this changed is explained to is to point out that we are moving into the fourth industrial revolution[8],

Accountants have been in the forefront of this important change. Not all accountants, but enough accountants. The American Institute of Certified Public Accountants (AICPA) nurtured technologies such as the Extensible Business Reporting Language (XBRL).

Personally, I have spent 20 years working with XBRL; creating the standard, constructing XBRL taxonomies for US GAAP and IFRS, building software tools that leveraged the structured information provided by XBRL, and creating what amounts to the world's first expert system for creating general purpose financial reports using US GAAP, IFRS, or any other reporting scheme for that matter[9].

This document is a synopsis of the important notes that I have collected during that time summarized, synthetized, and otherwise organized as best as I can. What is included is information that I found the most helpful and important to me. Likely, it will also be important information for you.

It is a risky time for professional accountants. Snake oil salesmen that don't have your best interest in their hearts will try and sell you the latest and greatest AI software. This document will help you not get duped. It will make you an informed buyer so you can ask good questions and make good choices. This information will also help you better serve your clients.

"The map is not the territory"

The territory has changed. A paradigm shift has occurred. A paradigm is a model, perspective, or set of ideas that form a worldview underlying the theory and methodology of a particular domain.

But many accountants and auditors are still using the same map, or mental model, that they have used for 100 years to think about accounting and auditing. That map is outdated. As Stephen Covey pointed out in his seminal book, *The Seven Habits of Highly Effective People*[10], it

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[8] 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

[9] Charles Hoffman, CPA, *Modern Approach to Creating a Financial Reporting Scheme*, http://xbrl.squarespace.com/journal/2019/12/19/modern-approach-to-creating-a-financial-reporting-scheme.html

[10] Stephen R. Covey, *The Seven Habits of Highly Effective People*, page 23.

is like being in Chicago and having a map of Detroit and trying to use that map of Detroit to make it to a specific location in Chicago. It is very frustrating and tends to be rather ineffective.

In order to understand the changes that are occurring we first need to help professional accountants update their mental map for thinking about computers, accounting, reporting, auditing, and analysis. The paradigm has already shifted, the world has changed and there is no going back.

What will become of human professional accountants in a world where computers play an increasing role in accounting, reporting, auditing, and analysis? As in many other spheres of knowledge touched by digital; accountants who survive and thrive will have an intimate understanding of the limitations of their machine assistants. These accountants will be part accountant bringing their broad domain knowledge, have good understanding of the real capabilities of their machine-based collaborators, and adept at asking valuable "what if" type questions which are beyond the capabilities of machines.

Rearranging Abstract Symbols

Computers sometimes seem to perform magic. But computers are really simply machines that follow very specific instructions. Skilled craftsmen, who wield their tools effectively, providing the correct machine-readable instructions, create what seems to be magic.

In his book *Saving Capitalism*[11], Robert Reich describes three categories that all modern work/jobs fit into:

- **Routine production services** which entails 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

[11] Robert B. Reich, *Saving Capitalism*, Alfred A. Knopf, page 204-206, (see a summary from *The Work of Nations* here http://www.oss.net/dynamaster/file_archive/040320/e8eb8748abfe77204a145d5fbcc892fb/OSS1993-01-37.pdf#page=6)

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

Many tasks in accounting, reporting, auditing, and analysis are related to symbolic-analytic services.

Shelly Palmer breaks work tasks down in another way[12]. 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. He 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.

Computers are Dumb Beasts

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[13]; 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
- **process stored information** reliably and efficiently, mechanically repeating the same process over and over

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

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

- **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.

Difference Between Data and Information

There are specific differences between data, information, knowledge, and wisdom[14]:

- **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.
- **Wisdom** (or Intelligence or Understanding): 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.

[14] Wikipedia, *DIKW Pyramid*, retrieved February 24, 2016, https://en.wikipedia.org/wiki/DIKW_Pyramid

Standards Minimize but Don't Eliminate Idiosyncrasies

Standards can be created to minimize the idiosyncrasies of both business professionals and information technology professionals. A complete discussion of how standards can be useful in minimizing idiosyncrasies is beyond the scope of this document. But I will point out that standard shipping containers, uniform product codes, standard electrical outlets, standard measurement tools, and other such standards are quite useful[15].

That said, people will be people. Fads, trends, personal preferences, fallacies, misinformation and other dynamics impact people's choices. They always have and they always will. As such, it is highly unlikely that you can get everyone to agree on something ever. So, multiple options can be a very good thing. Whether someone's needs are truly different or perceived to be different; having multiple alternatives rather than one single alternative can be a very good thing.

Except, when it is not. Agreeing to agree is great when it is possible. There is truly art and science involved in properly balancing something to get that something to work in equilibrium.

The important thing to keep in mind is that standards do exist and when employed appropriately they can save a lot of time and money.

The role of standards tends to be misunderstood and often under appreciated. These standards make things easier. There are many different standards such as intermodal shipping containers[16], universal product codes, the metric system, JPEG photo format, MPEG audio format, etc. Simply put, standards make things easier for users. XBRL is a global standard knowledge media[17].

XBRL is an ontology-like thing for representing financial reports digitally. XBRL can also be used for general business reports containing nonfinancial information. XBRL can be leveraged for automation of accounting, reporting, auditing, and analysis processes.

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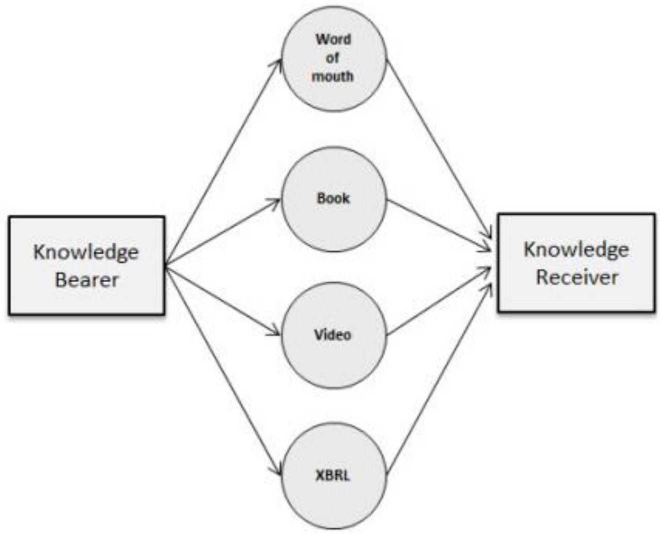
[15] Standards Make Markets, http://xbrl.squarespace.com/journal/2018/12/22/standards-make-markets.html

[16] Wikipedia, *Intermodal shipping container*, https://en.wikipedia.org/wiki/Intermodal_container#Specifications

[17] *Understanding that XBRL is a Knowledge Media*, http://xbrl.squarespace.com/journal/2017/1/16/understanding-that-xbrl-is-a-knowledge-media.html



In order to make use of a knowledge media effectively, the following three conditions must be satisfied:

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. The result cannot be a "black box" or a guessing game and users of the information should not be able to derive different knowledge simply by using a different software application.
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. Sigma level 6[18] is a good benchmark, 99.99966% accuracy.

Classification Systems

Things in the world are defined by their relations to one another; these explicit relations matter in creating logical definitions. A classification system is a logical grouping of something based on some similarity or criteria. A classification system is a communications tool. A classification system structures information. A classification system can be informal or formal, more

[18] Wikipedia, *Sigma Levels*, retrieved February 24, 2016, https://en.wikipedia.org/wiki/Six_Sigma#Sigma_levels

rigorously or less rigorously created, readable/usable by computers, or not. A classification system can be a controlled vocabulary. Classification systems can be categorized as follows:

- A **dictionary** or list or catalog is a classification system that tends to provide descriptions without much, or any, structure. Dictionaries or lists simply provide a flat inventory of terms with no relations expressed between the terms. (But even a dictionary classifieds terms into noun, verb, adverb, etc.)
- A **thesaurus** is a classification system that tends to document relations between broader terms and narrower terms. Another term for broader and narrower is generalization and specialization.
- A **taxonomy** is a classification system which tends to provide descriptions and a limited amount of structure generally in the form of one hierarchy into which some list of terms is categorized. Categories are basically sets. A taxonomy is a tree of categories of things with only one relation expressed so terms appear in only one location in a hierarchy of categories. A creator of a taxonomy creates concepts, creates coherent definitions for those concepts, and puts concepts into "buckets" or categories.
- An **ontology** is a classification system which tends to provide descriptions and multiple structures and therefore tends to have more than one hierarchy into which terms are categorized. So, an ontology can be thought of as a set of taxonomies for explicitly differentiate types of relations or associations between terms. An ontology can express many different types of relations which includes traits/qualities of each term and assertions or rules. An ontology is less like a tree and more like a graph[19] (network theory). This distinction is very important. The creator of an ontology identifies and establishes models explaining how things in a given ontology are related to one another, the kinds of relationships that exist, the rules of the model. If an ontology provides enough information, it can describe a conceptual model.
- A **logical theory** is a classification system where a set of axioms, a set of theorems, and a world view describe some logical theory or logical system. A logical theory can describe a conceptual model or conceptualization.

There are many other different types of classification systems including relational databases, topic maps, entity relations diagrams, XML schemas, UML models, etc. Essentially, they all are different ways of doing the same thing and each approach can achieve some specific level of expressiveness.

[19] Wikipedia, *Network Theory*, retrieved February 24, 2016; https://en.wikipedia.org/wiki/Network_theory

Understanding the Power of 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[20], 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[21]". 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[22] 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*.

Understanding Ontology

The following definition of an ontology is taken from the textbook *Ontology Engineering*[23] by Elisa Kendall and Deborah McGuinness:

Ontology - a model that specifies a rich description of the

- terminology, concepts, nomenclature;
- relationships among and between concepts and individuals; and
- sentences distinguishing concepts, refining definitions and relationships (constraints, restrictions, regular expressions)

relevant to a particular domain or area of interest.

[20] Lois Tilton, *From Aristotle to Linnaeus: the History of Taxonomy*, https://davesgarden.com/guides/articles/view/2051
[21] Wikipedia, *Graph Theory*, https://en.wikipedia.org/wiki/Graph_theory
[22] Maël Fabien, *Introduction to Graphs (Part 1)*, https://towardsdatascience.com/introduction-to-graphs-part-1-2de6cda8c5a5
[23] Elisa Kendall and Deborah McGuinness, *Ontology Engineering*, https://www.amazon.com/Ontology-Engineering-Synthesis-Lectures-Semantic/dp/1681733080

But as I pointed out, there are many different approaches to representing the information found in what many people call an ontology[24]. Further, there are many different ontology-like things[25].

Most business professionals probably have a vague understanding of what an ontology actual is or may not have ever heard the term at all. Those familiar with XBRL might be familiar with the term 'XBRL taxonomy'. Fundamentally, an ontology is an artifact that a software application can refer to and manipulate. The artifact can exist in any number of physical formats. But the essence is that an ontology is a logic-based classification system representation of information that a computer can process.

Spectrum of Knowledge Representation and Therefore Reasoning Capabilities

There is a direct correlation between the capabilities of a logical system to represent knowledge in machine-readable form, the actual knowledge represented in that machine-readable form, and the ability of software applications to read and then process that knowledge and perform useful work for the user of the software.

A graphic created by Dr. Leo Obrst explains this spectrum well[26]. I took Dr. Obrst's graphic, modified it slightly, and then came up with the graphic that you see below that explains the spectrum[27].

Note that a CSV file and spreadsheet are at the very bottom of the spectrum, week logical system and low reasoning capability. Stronger logic and reasoning capabilities are provided by ontologies such as OWL and other ontology-like things such as a logical theory.

Note that when XBRL is used correctly it has the capability to represent a logical theory[28]. Likewise, OWL + RDF + SWRL could be used with the same result. Similarly, proprietary approaches could be used.

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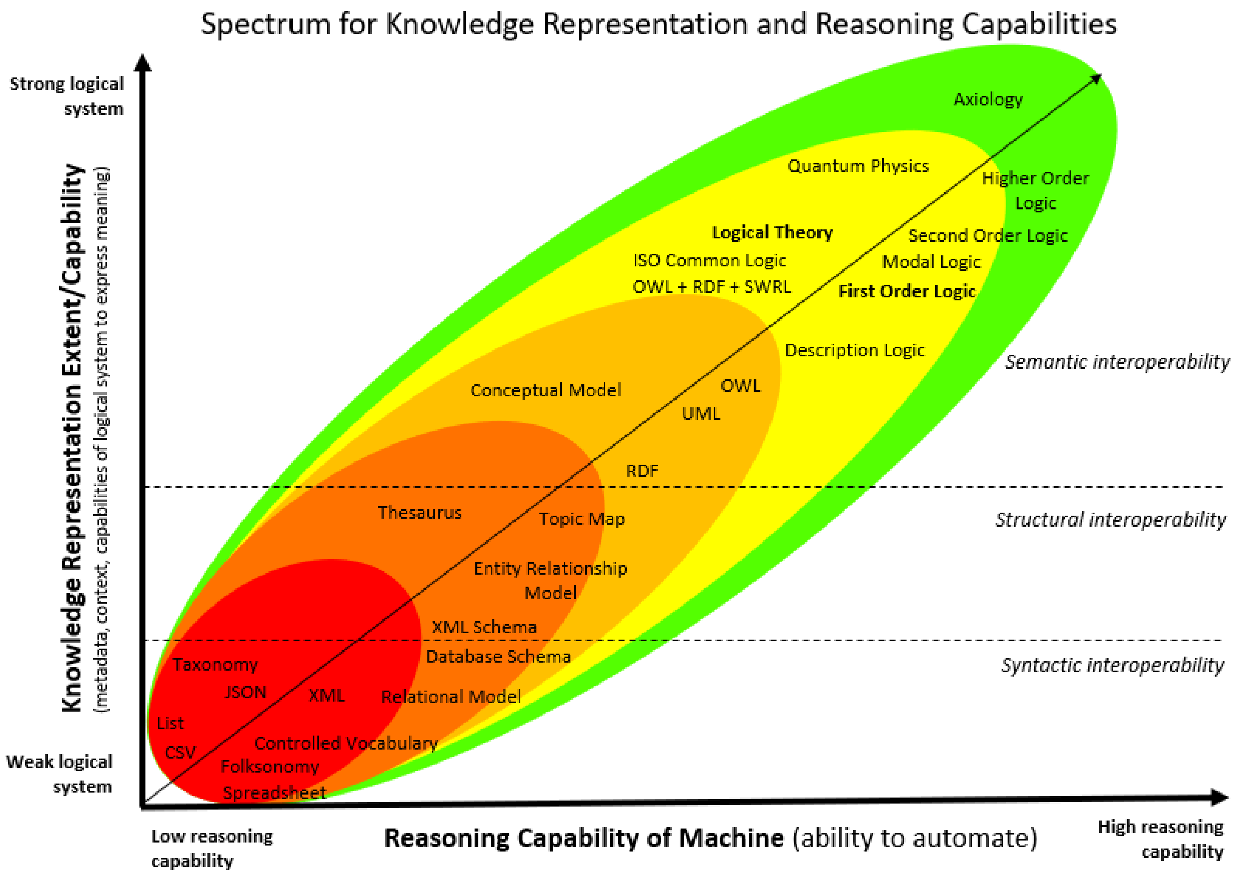
[24] Chris Irwin Davis, PhD, *Ontologies, Taxonomies, and Bears—Oh, My!*, https://www.linkedin.com/pulse/ontologies-taxonomies-bearsoh-my-chris-irwin-davis-phd/
[25] Charles Hoffman, CPA, *Ontology-like Things for Industry*, http://xbrl.squarespace.com/journal/2019/7/13/ontology-like-things-for-industry.html
[26] Mills Davis, *AI – Externalization of Mind*, slide 60, https://www.slideshare.net/Mills/ai-externalization-of-mind-81319464
[27] Charles Hoffman, CPA, *Revisiting the Knowledge Representation Spectrum*, http://xbrl.squarespace.com/journal/2019/10/9/revisiting-the-knowledge-representation-spectrum.html
[28] 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

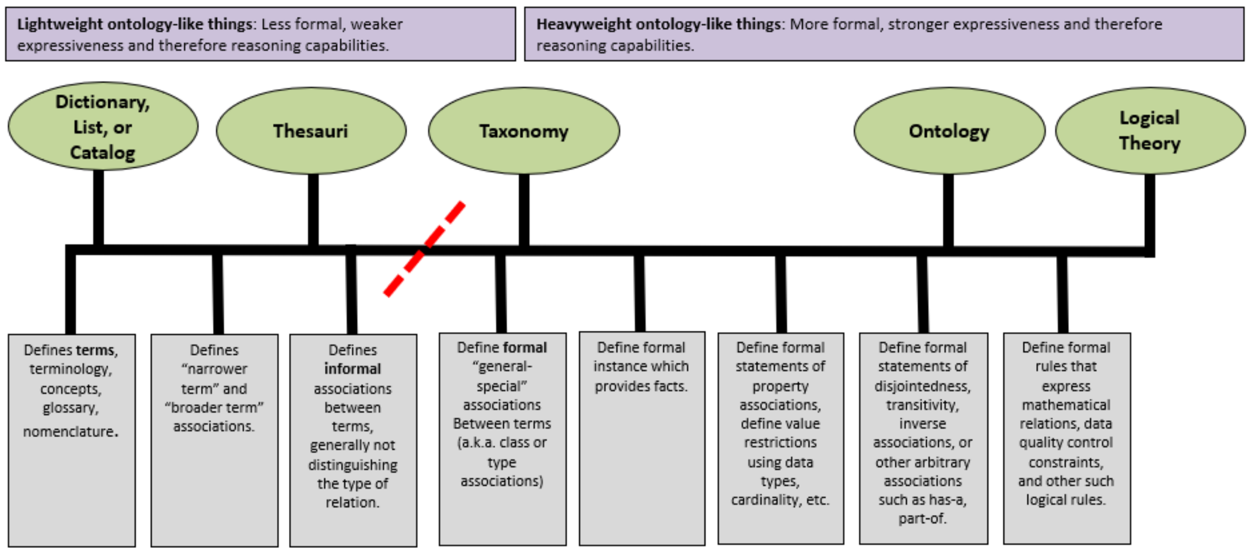


Modified version, inspired by original similar graphic created by Dr. Leo Obrst, Mitre, and Mills Davis, Project10x
Mills Davis, *AI - Externalization of Mind*, slide 60, https://www.slideshare.net/Mills/ai-externalization-of-mind-81319464

Ontology-Like Things

The different types of classification systems form a spectrum. Some knowledge engineering textbooks refer to this as the *ontology spectrum*[29]. Michael Uschold's insightful explanation of an ontologies his presentation *Ontologies and Semantics for Industry*[30] uses the term **ontology-like thing** to describe this spectrum. Here is a graphic of the ontology spectrum or ontology-like things:

[29] *Ontology Spectrum*, http://xbrl.squarespace.com/journal/2019/4/27/ontology-spectrum.html
[30] Michael Uschold, *Ontology-like Things for Industry*, http://xbrl.squarespace.com/journal/2019/7/13/ontology-like-things-for-industry.html



The following is an enhanced description of an ontology-like thing that is approachable to business professionals. This definition is inspired and synthesized from the basic textbook definition of an ontology provided in *Ontology Engineering* by Elisa Kendall and Deborah McGuinness; Michael Uschold's insightful description of an ontology-like things in his presentation *Ontologies and Semantics for Industry*; and Shawn Riley's description of an ontology's common components in *Good Old-Fashioned Expert Systems (With or Without Machine Learning)*[31]. Adding a few other odds and ends, I came up with the following definition:

An **ontology or ontology-like thing** is a model that specifies a rich and *flexible* description of the *important relevant*

- **terms** (terminology, concepts, nomenclature; includes primitive terms and functional terms);
- **relations** (relationships or associations among and between concepts and individuals; is-a relations, has-a relations; other properties);
- **assertions**: (sentences distinguishing concepts, refining definitions and relationships including constraints, restrictions; axioms, theorems, restrictions);
- **facts**: (facts, individuals, instances)
- **world view**: (reasoning assumptions, identity assumptions)

relevant to a particular domain or area of interest, which generally allows for some certain specific variability, and as consciously unambiguously and completely as is necessary and practical in order to achieve a specific goal or objective or a range of goals/objectives. It enables a community to agree on important common terms for capturing meaning or

[31] Shawn Riley, *Good Old-Fashioned Expert Systems (With or Without Machine Learning)*, https://www.linkedin.com/pulse/good-old-fashioned-ai-expert-systems-shawn-riley/

representing a shared understanding of and knowledge in some domain where flexibility/variability is necessary.

And so, the reason for creating an "ontology-like thing" is to make the meaning of a set of terms, relations, and assertions explicit, so that both humans and machines can have a common understanding of what those terms, relations, and assertions mean. "Instances" or "sets of facts" (a.k.a. individuals) can be evaluated as being consistent with or inconsistent with some defined ontology-like thing created by some community. The level of accuracy, precision, fidelity, and resolution expressively encoded within some ontology-like thing depends on the application or applications being created that leverage that ontology-like thing.

Good, Less Good, Bad, and Worse Ontology-like things

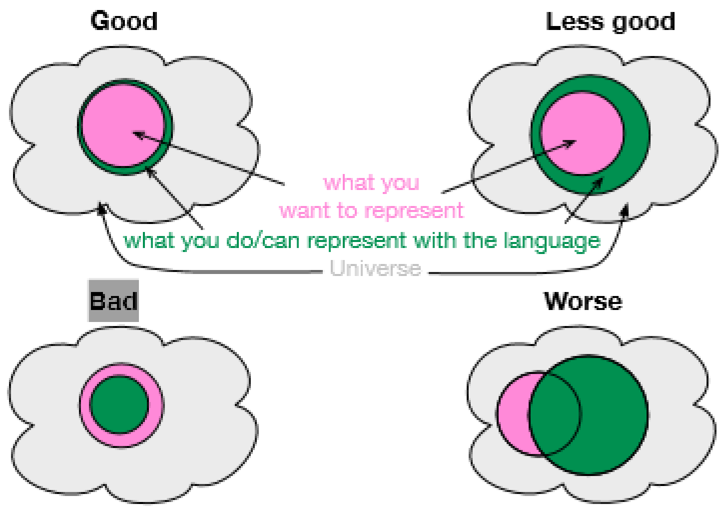
In her book *An Introduction to Ontology Engineering*[32], C. Maria Keet, PhD, provides discussion about what constitutes a good and perhaps a not-so-good ontology. She discusses the notion that a syntax error in an ontology is similar to computer code not being able to compile. She discusses the notion of logical errors within an ontology-like thing which cause the ontology to not work as expected.

Finally, Keet discusses the notions of *precision* and *coverage* when it comes to judging whether an ontology or ontology-like thing is good or bad and provides a set of four graphics that drive this point. Precision can be low or high; coverage can likewise be low or high.

You get a good ontology when the precision of the ontology is high and the coverage of the ontology is high. *Precision* is a measure of how precisely you do or can represent the information of a domain within an ontology-like thing as contrast to reality. *Coverage* is a measure of how well you do or can represent a domain of information within an ontology-like thing.

If you represent the things that you should represent (i.e. your coverage is good) and you do so such that the ontology-like thing accurately represents reality, then you get a good ontology-like thing. But if an ontology-like thing cannot do what it should be able to do then it is a bad ontology-like thing. And things can go wrong when you have high precision but not enough coverage or if you have low precision with high coverage or things can become really bad if neither your precision nor coverage are what you should have created given the goal you are trying to achieve.

[32] C. Maria Keet, *An Introduction to Ontology Engineering*, pages 8-9, https://people.cs.uct.ac.za/~mkeet/files/OEbook.pdf



And so, precision and coverage matter when it comes to creating an ontology-like thing.

Ontological Commitment

An **ontological commitment** is an agreement by the stakeholders of a community to use some ontology-like thing in a manner that is consistent with the theory of how some domain operates represented by the ontology-like thing. The commitment is made in order to achieve some specific goal or goals established by the stakeholders in a community sharing the ontology-like thing.

The ontology-like thing is a lot like the conductor of an orchestra.

Testable and Provable Logical System

Testing is used to be sure an ontology-like thing has good precision and good coverage. The ontology-like thing and instances (values) created per that ontology-like thing form a sharable conceptualization or logical system[33] (logical theory) that can be tested and proven to be:

- **Consistent** (no assertions of the system contradict another assertion)
- **Valid** (no false inference from a true premise is possible)
- **Complete** (if an assertion is true, then it can be proven; i.e. all assertions exists in the system)
- **Sound** (if any assertion is a theorem of the system; then the theorem is true)

[33] Wikipedia, *Logical System*, https://en.wikipedia.org/wiki/Logic#Logical_systems

- **Fully expressed** (if an important term exists in the real world; then the term can be represented within the system)

Think of a logical system that is consistent, valid, complete, sound, and fully expressed. Now, imagine removing one assertion from the system. Removing that one assertion could let incorrect information into the system which would cause information quality issues.

Ontology-like things for accounting, reporting, auditing, and analysis require high-quality and therefore they require highly expressive ontology-like things.

Controlling Logical System Variability

Every word used to describe an ontology-like thing is there for a reason. The term "flexible" is included in the definition to indicate that we are not talking about a form. The logical systems we are concerned with have a certain amount of variability and alternatives are allowed, and so the logical system needs to be extensible. This extensibility is not arbitrary or random; the extensibility must be carefully and deliberately controlled.

The logical system needs to be predictable, reliable, and safe; free from catastrophic failures which would cause undesirable instability.

As pointed out in the ontology spectrum; a dictionary, a thesaurus, a taxonomy, an ontology, and a logical theory are all different types of ontology-like things. All types are useful, but what you are trying to get out of the system needs to be matched to what you put into the ontology-like thing. Again, if you leave one assertion out, errors could creep into the logical system.

There are all sorts of other things that provide the same sorts of functionality as ontology-like things. Many times terms used are different, definitions are somewhat different, what is trying to be achieved is different. These differences tend to cause confusion and complexity. But the differences tend to be small and the similarities more significant.

Fads, trends, misinformation, politics, and arbitrary preferences all tend to cause distractions from the real choices that need to be made. The real focus should be on the fact that artificial intelligence applications are brought to life by the metadata provided by ontology-like things. You need to create an ontology-like thing that provides that metadata in order to achieve your objective or goal.

In particular, high quality curated metadata provided by an ontology-like thing will supercharge these sorts of applications. Some people say that data is the new oil. As we will point out in a moment that if data is the new oil, metadata is the new gold.

Common Components of an Ontology-like Thing

Explaining all the details of how to create an ontology is beyond the scope of this document, we will leave that to knowledge engineering textbooks. However, I do want to provide you with just a little more detail. I reconcile that definition above to the common components of an ontology-like thing that I summarize in the document *Demystifying the Role of Ontologies in XBRL-based Digital Financial Reporting*[34] as follows:

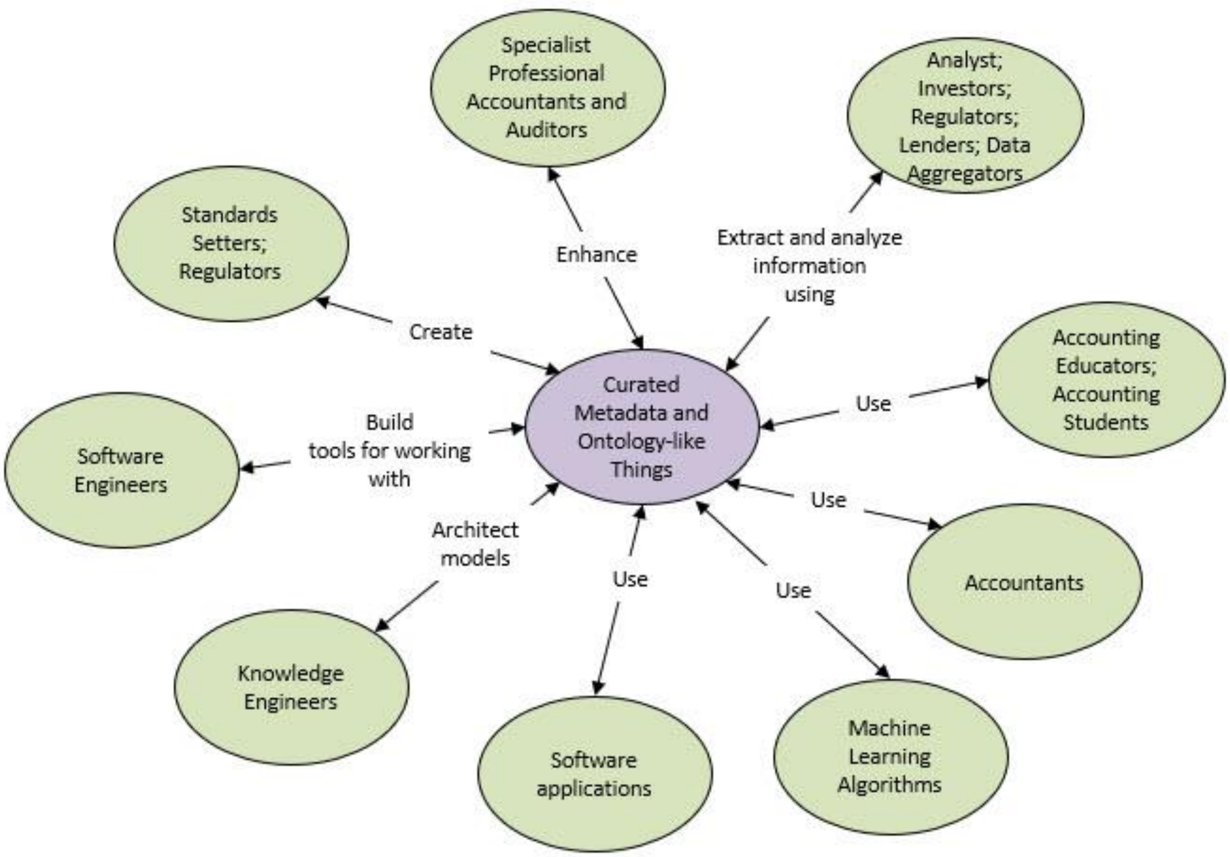
- **Terms** (things)
    - Simple terms (primitive, atomic)
    - Functional component terms (complex functional terms)
    - Properties (qualities, traits)
- **Relations** (associations between things)
    - Type relations (class/type relations, "type-of" or "is-a" or "class-subclass" or "general-special")
    - Functional relations (structural relations, context, "has-a" or "part-of" or "has-part" or "whole-part")
    - Property attribution (has property)
- **Assertions** (rules things and associations follow)
    - **Axioms** (Axioms describe self-evident logical principles related to a domain that no one would argue with.)
    - **Theorems** (rules; Theorems are logical deductions which can be proven by constructing a chain of reasoning by applying axioms or other theorems in the form of IF…THEN statements.)
    - **Restrictions** (restrictions, constraints, limitations, ranges)
- **Facts** (individuals)
    - Instance (facts; values)
- **World view**
    - Closed world assumption
    - Unique name assumption
    - Negation as failure

A master craftsman using the right tools can put these pieces together in a manner that will supercharge software applications that assist humans in performing useful work.

[34] Charles Hoffman, CPA, *Demystifying the Role of Ontologies in XBRL-based Digital Financial Reporting*, pages 7-9, http://xbrlsite.azurewebsites.net/2019/Library/DemystifyingOntologies.pdf

Common, Shared Understanding

Put the pieces together correctly and an ontology-like thing provides a common, shared conceptualization[35] that can be effectively used by a community or supply chain to achieve some objective or range of objectives. The curated machine-readable metadata provided by the ontology-like thing supercharges the functionality provided by software applications to serve the needs of the community:



The curated metadata provided by ontology-like things plays a central role and will supercharge accounting, reporting, auditing, and analysis in a digital environment.

Acquiring a Thick Metadata Layer

A key ingredient to a computer-based system is metadata. The power of a computer system is proportional to the high-quality metadata available. What is not in dispute is the need for a

[35] Nicola Guarino, Daniel Oberle, and Steffen Staab, *What is an Ontology?*, page 3 What is a Conceptualization, http://www.iaoa.org/isc2012/docs/Guarino2009_What_is_an_Ontology.pdf

"thick metadata layer" and the benefits of that metadata in terms of getting a computer to be able to perform useful and meaningful work.

An ontology-like thing is a mechanism for creating and maintaining metadata.

But what is sometimes disputed is *how* to most effectively and efficiently get that thick metadata layer. There are two basic approaches to getting this thick metadata layer:

- **Have the computer figure out what the metadata is**: This approach uses artificial intelligence, machine learning, and other high-tech approaches to detecting patterns and figuring out the metadata.
- **Tell the computer what the metadata is**: This approach leverages business domain experts and knowledge engineers to piece together the metadata so that the metadata becomes available in the form of an ontology-like thing.

Because knowledge acquisition can be slow and tedious, much of the future of computer systems depends on breaking the metadata acquisition bottleneck and in codifying and representing a large knowledge infrastructure. However, this is not an “either/or” question. Both manual and automated knowledge acquisition methods can be used together. Manually created ontology-like things are used to prime the pump; then machine learning can build on that foundation.

And so fundamentally, the idea behind artificial intelligence (AI) is to get software algorithms to learn or be trained to do something without specifically hard coding one specific set of directions. One way of achieving this is to provide software with a set of rules. That is how expert systems (rules-based systems) work. A second approach is to have software detect patterns and figure out the rules themselves. That is how machine learning (patterns-based systems) work.

Finally, nothing about processing information within this logical system can be a “black box”. The innerworkings must be provided in a human-readable manner. Information provenance must be knowable and traceable. Auditable algorithms are essentially ones that are explainable. Algorithms, including artificial intelligence, used by the enterprise or for accounting, reporting, auditing, and analysis needs to be explainable artificial intelligence[36]. Explainable AI (XAI) provides insight into how the software algorithms reached its conclusions, an understandable “line of reasoning”.

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

Curated Metadata

Some people say that data is the new oil.[37] In fact, the Economist declares this in the article, "*The world's most valuable resource is no longer oil, but data*[38]." Other people say, "*If data is the new oil, then metadata is the new gold.*"[39]

If you read this article, *Data Curation: Weaving Raw Data into Business Gold (Part 1)*[40], the author uses crude oil, refined gasoline, and refined racing fuel as a metaphor to explain the value of metadata. Metadata is simply data about data. An ontology-like thing is machine-readable metadata.

Carol Smith puts it this way: "AI is taxonomies and ontologies coming to life."[41]

Curated metadata[42] provides what is necessary to make artificial intelligence to work, to supercharge AI. But creating that metadata takes a lot of work. But it also establishes the solid foundation that you need and can then build on.

Business Rules are Metadata

The Merriam-Webster dictionary defines anarchy[43] 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." Business rules prevent information anarchy[44]. Business rules are metadata.

Business rules enable a knowledge bearer to describe information they are providing and verify that the information provided is consistent with that description. Business rules enable a

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[37] Joris Toonders, *Data Is the New Oil of the Digital Economy*, Wired, https://www.wired.com/insights/2014/07/data-new-oil-digital-economy/
[38] The Economist, *The world's most valuable resource is no longer oil, but data*, https://www.economist.com/leaders/2017/05/06/the-worldsmost-valuable-resource-is-no-longer-oil-but-data
[39] Julian Ereth, *If data is the new oil, then metadata is the new gold*, https://www.eckerson.com/articles/if-data-is-the-new-oil-metadata-is-thenew-gold
[40] Bill Schmarzo, *Data Curation: Weaving Raw Data Into Business Gold (Part 1)*, https://www.digitalistmag.com/cioknowledge/2019/04/29/data-curation-weaving-raw-data-into-business-gold-part-1-06197968
[41] Carol Smith, *AI and Machine Learning Demystified*, slide 12, https://www.slideshare.net/carologic/ai-and-machine-learning-demystified-by-carol-smith-at-midwest-ux-2017/
[42] Charles Hoffman, CPA, *Modern Approach to Creating a Financial Reporting Scheme*, http://xbrl.squarespace.com/journal/2019/12/19/modern-approach-to-creating-a-financial-reporting-scheme.html
[43] Anarchy definition, Merriam-Webster, http://www.merriam-webster.com/dictionary/anarchy
[44] *Understanding that Business Rules Prevent Anarchy*, http://xbrl.squarespace.com/journal/2016/7/15/understanding-that-business-rules-prevent-anarchy.html

knowledge receiver to understand the description of information provided by the knowledge bearer and likewise verify that the information is consistent with that description.

Business rules guide, control, suggest, or influence behavior. Business 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. Business rules help shape judgment, help make decisions, help evaluate, help shape behavior, and help reach conclusions.

Business rules arise from the best practices of knowledgeable business professionals. A business 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 business rules are a choice of business professionals. The meaning of a business rule is separate from the level of enforcement someone might apply to the rule.

A business rule states a fact about the world (declarative rule). A business rule can provide instructions (production rule). Business rules are metadata.

The term **assertion** is a synonym for business rule.

Categories of Business Rules

At their essence, business rules articulate information about something or about the relationship between (a.k.a association) one thing and some other thing. Some examples that can help you better understand exactly what business rules are:

- **Axioms**: Axioms describe self-evident logical principles related to a domain that no one would argue with. For example, “Assets = Liabilities and Equity”, the accounting equation, is an axiom. It is true by definition.
- **Theorems**: Theorems are logical deductions which can be proven by constructing a chain of reasoning by applying axioms or other theorems in the form of IF…THEN statements.
- **Restrictions**: A restriction is a constraint usually mandated by some authority.
- **Constraints**: For example, specific behavioral constraints that control when it is appropriate to create, update, or remove information.
- **Limits**: A limit is similar to a constraint.

- **Computations**: For example, calculating things, such as "Total Property, Plant and Equipment = Land + Buildings + Fixtures + IT Equipment + Other Property, Plant, and Equipment".
- **Continuity cross-checks**: For example, if a fact is used in one fact set that fact does not conflict with or contradict other facts in some other fact set.
- **Process-oriented rules**: For example, the disclosure checklist commonly used to create a financial statement which might have a rule, "If the line item Property, Plant, and Equipment exists on the balance sheet, then a Property, Plant and Equipment policies and disclosures must exist."
- **Regulations**: Another type of rule is a regulation which must be complied with, such as "The following is the set of ten things that must be reported if you have Property, Plant and Equipment on your balance sheet: depreciation method by class, useful life by class, amount under capital leases by class, ..." and so on. Many people refer to these as reportability rules or statutory and regulatory compliance requirements.
- **Instructions or documentation**: Rules can document relations or provide instructions, such as "Cash flow types must be either operating, financing, or investing."
- **Relations**: How things can be related or associated, such as whole-part relations. For example, how the business segments of an economic entity are related.

Artificial Intelligence

Artificial intelligence[45] is a branch of computer science. There are many good descriptions of artificial intelligence[46]. Here is one good definition:

> Artificial intelligence is the automation of activities that we associate with human thinking and activities such as decision making, problem solving, learning and so on.

Another more neutral term than artificial intelligence is the term machine intelligence[47] which has the same meaning. Think of these tools as narrowly focused employees with great memories that are very good at performing one specific repetitive task well, over, and over, and over. Literally, like a machine.

Those trying to make artificial intelligence work over the past 40 or so years have had limited success[48]. But that is changing. People are putting the pieces together and the technologies

[45] *Introduction to Artificial Intelligence Terminology*, http://xbrl.squarespace.com/journal/2016/7/21/introduction-to-artificial-intelligence-terminology.html
[46] AlanTuring.net, *What is Artificial Intelligence?*, http://www.alanturing.net/turing_archive/pages/reference%20articles/What%20is%20AI.html
[47] Shivon Zilis and James Cham, Harvard Business Review, *The Competitive Landscape for Machine Intelligence*, https://hbr.org/2016/11/the-competitive-landscape-for-machine-intelligence
[48] John F. Sowa, *Why Has AI Failed? And How Can it Succeed?*, http://www.jfsowa.com/pubs/micai.pdf

created from AI research are now available to experiment with. If expectations are not set too high, very useful functionality for limited, narrow problems can be successfully created.

Ray Dalio explains artificial intelligence in terms understandable to business professionals in the article *Systemized and Computerized Decision Making*[49].

One good example of using artificial intelligence is driverless cars. Many people get confused as to what is truly achievable and practical when it comes to driverless cars. Driverless cars are on the streets of Singapore today[50]. While still in prototype mode now to work out details, by 2018 these taxis are anticipated to be commercially available. Uber is testing autonomous cars in Pittsburg[51]. Attempting to have a driverless car navigate the streets of a large city is a different problem than having a driverless truck navigate from one major city to another city on a freeway.

One of the best ways to understand the true capabilities of artificial intelligence is to try it out. Go test drive a Tesla which has driver-assist features. Use driver assist on the freeway then use driver assist on a windy, hilly road with no painted striping to indicate lanes. Which do you think might work best?

Remember that there are two major techniques for implementing artificial intelligence: expert systems and machine learning. And remember that there are two approaches for getting the metadata you need to make the artificial intelligence system work: humans creating the metadata manually or machine learning.

There are two types of artificial intelligence, specialized and generalized:

- **Specialized**: An example of specialized artificial intelligence is programming a computer to play chess. The software performs one specific task. Specialized artificial intelligence is fairly easy to achieve.
- **Generalized**: An example of generalized artificial intelligence is the sort of science-fiction stuff you see in the movies. With generalized artificial intelligence, computers can perform multiple tasks or be generally intelligent. Why do you only see this in the movies? Because generalized artificial intelligence is extremely hard to make work.

[49] Ray Dalio, *Systemized and Computerized Decision Making*, http://xbrl.squarespace.com/journal/2020/5/18/ray-dalio-systemized-and-computerized-decision-making.html

[50] Reuters, *First driverless taxis hit the streets of Singapore*, http://www.reuters.com/article/us-autos-selfdriving-singapore-idUSKCN1100ZG

[51] The Atlantic, *Anybody Can Test a Driverless Car in Pennsylvania*, http://www.theatlantic.com/technology/archive/2016/09/anybody-can-test-a-self-driving-car-in-pennsylvania/499667/

Another differentiator of artificial intelligence is "weak AI" and "strong AI"[52]:

- **Weak AI**: With weak AI, artificial intelligence relies heavily on information provided by humans and can only simulate human behavior.
- **Strong AI**: With strong AI, the artificial intelligence can process and make independent decisions.

Strong, generalized artificial intelligence is 50 to 100 years in the future if you ask most experts. And general intelligence might not even be achievable. But specialized weak artificial intelligence is here today.

The AI Ladder[53] points out that 81% of business leaders to not understand AI, not having a handle on your data is completely paralyzing, and the lack of the right skills on part of both business professionals and information technology professionals is problematic. Self-assessing your true understanding of AI and filling in any gaps is essential to adapting to your new future.

Reasoning Methods

There are four different reasoning methods[54] which are:

- **Deduction**: Deriving implications from premises.
- **Induction**: Deriving general principles from examples.
- **Abduction**: Forming a hypothesis that must be tested by induction and deduction. Involves inferring the best or most plausible explanation from a given set of facts or data.
- **Analogy**: Besides these three types of reasoning there is a fourth, analogy, which combines the characters of the three, yet cannot be adequately represented as composite. Analogy is more primitive, but more flexible than logic. The methods of logic are disciplined ways of using analogy.

The four approaches are not mutually exclusive.

[52] Artificial Intelligence Blog, *Strong vs. Weak Artificial Intelligence*, https://e3zine.com/strong-artificial-intelligence/
[53] Rob Thomas, O'Reilly Media, *The AI Ladder*, http://xbrl.squarespace.com/journal/2019/10/19/the-ai-ladder.html
[54] John Sowa and Arun K. Majumdar, *Analogical Reasoning*, http://www.jfsowa.com/talks/iccs03.htm

Use the Right Artificial Intelligence Approach for the Job

There are two major techniques for implementing artificial intelligence[55]:

- **Logic and rules-based approach** (expert systems)[56]: Representing processes or systems using logical rules. Uses deductive reasoning.
- **Machine learning** (pattern-based approach)[57]: Algorithms find patterns in data and infer rules on their own. Uses inductive reasoning; probability.

You can combine both approaches and create a third approach which is a hybrid of both approaches.

Implementing a "good old fashion expert system[58]" is a lot of work. A logic and rules-based approach is based on what amounts to an ontology-like thing which can be hard to get right but once you have this high-quality curated information[59]; it can literally supercharge AI[60] and make it do wonderful and useful things. This is proven technology, it works, but it is expensive and time consuming to get right.

Many computer scientists would have you believe that machine learning or "deep learning" (they are the same thing) will help you get around all the hard work and expense of a logic and rules-based approach to implementing AI. But current machine learning type systems are being characterize as doing basically "cheap parlor tricks[61]" and they are a fragile house of cards rather than a solid foundation.

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,

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[55] Harry Surden, *Artificial Intelligence and Law Overview*, https://www.slideshare.net/HarrySurden/harry-surden-artificial-intelligence-and-law-overview/6-Major_AI_ApproachesTwo_Major_AI
[56] *Understanding Knowledge Based Systems*, http://xbrl.squarespace.com/journal/2017/5/3/understanding-knowledge-based-systems.html
[57] *Machine Learning*, https://www.firmai.org/documents/Machine%20Learning%20Bird's-eye/
[58] Shawn Riley, *Good Old Fashion Expert System*, https://www.linkedin.com/pulse/good-old-fashioned-ai-expert-systems-shawn-riley/
[59] *Curated Machine-Readable Information (also Human-Readable) is the Future*, http://xbrl.squarespace.com/journal/2019/6/14/curated-machine-readable-information-also-human-readable-is.html
[60] *AI is Taxonomies and Ontologies Coming to Life*, http://xbrl.squarespace.com/journal/2019/5/11/ai-is-taxonomies-and-ontologies-coming-to-life.html
[61] *Avoid Creating a Fragile House of Cards*, http://xbrl.squarespace.com/journal/2019/7/10/avoid-creating-a-fragile-house-of-cards.html

- relationships are difficult to describe adequately with conventional approaches.

Machine learning basically uses probability and statistics, correlations[62]. 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[63]. Ultimately, what you create will either work or it will not work to achieve your objectives.

There are no short cuts. No one disputes the need for 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. Machine learning works best if you already have a thick layer of metadata, that is the training data that machine learning needs to work.

Augmented Intelligence

In his book, *Principles*, Ray Dalio advises[64],

> “By developing a partnership with your computer alter ego in which you teach each other and each do what you do best, you will be much more powerful then if you went about your decision making alone.”

Augmented intelligence is about computers and humans working together rather than machines replacing humans. Augmented intelligence applications combine human and machine intelligence. This is important in systems there is low tolerance for error or where artificial intelligence is not evolved enough to take humans completely out of the loop. Another term for augmented intelligence is intelligence amplification[65].

Expert Systems

Expert systems[66] is a branch of artificial intelligence. Expert systems, also called knowledge-based systems or simply knowledge systems, are computer programs. The following is one definition of an expert system:

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[62] 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/

[63] 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/

[64] Ray Dalio, *Systemized and Computerized Decision Making*, http://xbrl.squarespace.com/journal/2020/5/18/ray-dalio-systemized-and-computerized-decision-making.html

[65] Wikipedia, *Intelligence Amplification*, https://en.wikipedia.org/wiki/Intelligence_amplification

[66] *Understanding the Components of an Expert System*, http://xbrl.squarespace.com/journal/2016/5/24/understanding-the-components-of-an-expert-system.html

> Expert systems are computer programs that are built to mimic human behavior and knowledge. Expert systems are for reconstructing the expertise and reasoning capabilities of qualified experts within some limited, narrow domain of knowledge in machine-readable form. A model of the expertise of a domain of knowledge of the best practitioners or experts is formally represented in machine-readable form and the expert system reaches conclusions or takes actions based on that information when trying to solve some problem. The computer program performs tasks that would otherwise be performed by a human expert.

Expert systems are the most commercially successful applications of artificial intelligence research[67]. There are currently thousands of expert systems employed world-wide in industry and government. Expert systems are driven by metadata.

Frank Puppe explains in his book *Systematic Introduction to Expert Systems*[68] that there are three general categories of expert systems:

- **Classification or diagnosis type**: helps users of the system select from a set of given alternatives. The system tends to be instructional in nature.
- **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 or create predictions based on the system.

The assembly of a financial report can be assisted by a construction-type expert system. Helping professional accountants understand what goes into that financial report can be assisted by a classification-type expert system. Creating forecasts and projections of future financial reports can be assisted by simulation-type expert systems.

Business Rules Engine

A business rules engine is a style of writing software. Anything achievable by a business rules engine is achievable by general functional programming. But, business rules engines can have an advantage in certain cases. For example, when you want to separate business logic from program logic and allow business professionals to control and maintain business rules.

A business rules engine, or rules engine, is a mechanism for executing business rules. Rules engines are optimized to figure out what rules apply to what facts and the order rules should be

[67] Edward Feigenbaum et. al, *KNOWLEDGE-BASED SYSTEMS IN JAPAN*, http://www.wtec.org/loyola/kb/execsum.htm

[68] Frank Puppe, *Systematic Introduction to Expert Systems, Knowledge Representations and Problem-Solving Methods*, page 11 (Note that you can read Parts I and II on Google Books here, https://books.google.com/books?id=_kKqCAAAQBAJ)

run and result is some consequence based on the facts and rules. A rules engine is a non-trivial application to create. The stronger the problem-solving logic of the rules engine supports, the more powerful the rules engine.

Creating an Expert System or Knowledge Based System

Creating a knowledge-based system[69] involves the transformation of machine-readable instructions in such a way as to explain to a machine how a system works and how to make a system work the way you want that system to work.

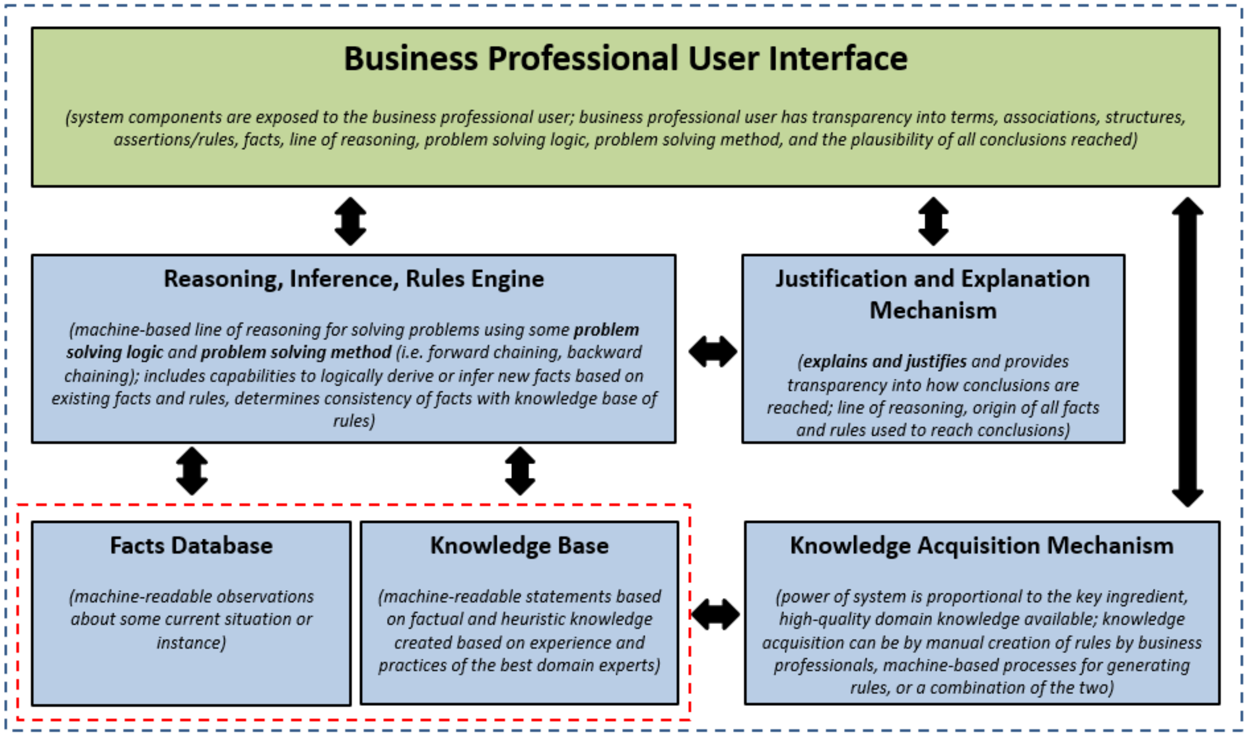
Then, brick-by-brick, much like building a house, business domain experts and software engineers can create tools that automate certain types of tasks in that process. Humans encode information, represent knowledge, and share meaning using machine-readable patterns, languages, and logic.

Components of a Knowledge Based System (Expert System)

Simply put, a **knowledge-based system** is a system that draws upon the knowledge of human experts 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.

Nothing is a "black box", rather every aspect of every decision made by a system is completely understandable to the business professional using the system. Below is a graphic of the components of a knowledge-based system:

[69] Another term used to describe such systems is reasoning system.



Shared View of Reality to Achieve a Specific Purpose

In his book[70] *Data and Reality*, William Kent provides an excellent summary that discusses the realities of sharing information. In Chapter 9: *Philosophy* in the Third Edition and Chapter 12: *Philosophy* in the first edition (which is available online) he paints a picture of why you want to go through the trouble of sharing information using machine-based processes and the realities of what that takes. This is what William Kent points out which I have paraphrased as it relates to financial reporting:

> To create a shared reality to achieve a specific purpose: To arrive at a shared common enough view of "true and fair representation of financial information" such that most of our working purposes, so that reality does appear to be objective and stable so that you can query information reliably, predictably, repeatedly, safely.

Meaningful information exchange that is reliable, repeatable, predictable, safe, cost effective, easy to use, robust, scalable, secure when necessary, auditable (track provenance) when necessary[71].

[70] William Kent, *Data and Reality*, Technics Publications, (See this resource which has CHAPTER 12: Philosophy from the first version of this book, http://www.bkent.net/Doc/darxrp.htm)
[71] Charles Hoffman, CPA, *Special Theory of Machine-based Automated Communication of Semantic Information of Financial Statements*,

Prudence dictates that using the information contained in a digital financial report should not be a guessing game. Safe, reliable, repeatable, predictable, reuse of reported financial information using automated machine-based processes is obviously preferable to a guessing game.

The effective meaningful exchange of information is created by skilled craftsmen that know their craft well. The craftsmen balance the system, bringing the system into equilibrium to achieve some specific purpose. Creating this shared view of reality which allows this specific purpose to be achieved has benefit to the financial reporting supply chain.

That purpose should be clearly defined so that everyone understands the objective and exactly what the system can, and cannot, deliver.

Principles help you think about something thoroughly and consistently. Overcoming disagreements between stakeholders and even within groups of stakeholders is important. Agreement between stakeholder groups and within stakeholder groups contributes to harmony. Lack of agreement contributes to dissonance. Principles help in the communications process.

I would argue that a first step, if not the first step, of arriving at harmony is outlining the interests, perceptions, positions, and risks of each constituency/stakeholder group.

A "stakeholder" is anyone that has a vested interest. Another term for stakeholder is "constituent". A "constituent" is a component part of something.

Foundational to arriving at harmony is having a common conceptual framework including a set of consistent principles or assumptions or world view for thinking about the system[72]. For example, accounting and financial reporting have such a conceptual framework including principles/assumptions such as "materiality" and "going concern" and "conservatism".

This "framework for agreeing" helps the communications process which increases harmony and decreases dissonance. This is about bringing the system into balance, consciously creating the appropriate equilibrium/balance.

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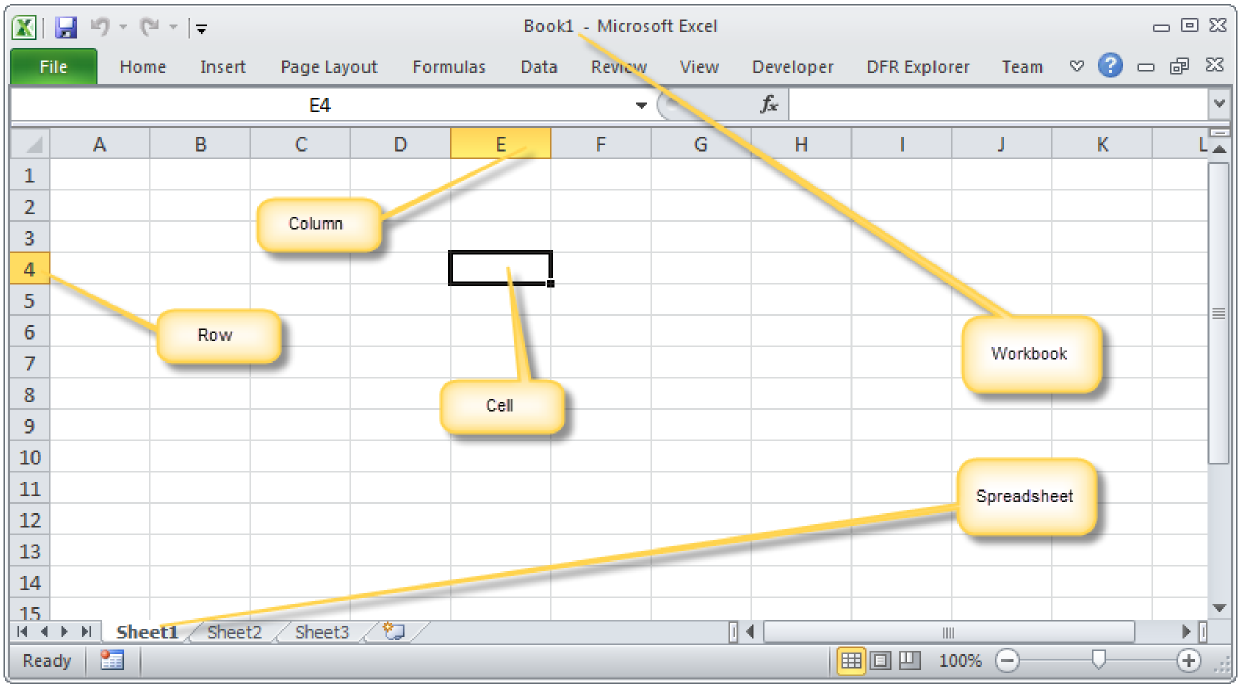
http://xbrlsite.azurewebsites.net/2019/Library/SpecialTheoryOfSemanticCommunicationOfFinancialInformation.pdf

[72] Charles Hoffman, CPA, *Systems Theory: Method to my Madness*, http://xbrl.squarespace.com/journal/2019/12/29/systems-theory-method-to-my-madness.html

Using Conceptual Models

Business professionals work with conceptual models every day. For example, the workbooks, spreadsheets, rows, columns, and cells of an electronic spreadsheet are a conceptual model. The ease and simplicity of an electronic spreadsheet allows the average business professional to make use of this helpful tool.



Differentiating a Notion/Idea/Phenomenon, a Name, and a Preferred label

It is important to understand and properly differentiate between the following three things:

- **Notion, idea, phenomenon**: something that exists in reality that needs to be represented
- **Name**: helps computers uniquely identify some notion/idea/phenomenon that is a representation of reality within some machine-readable conceptual model
- **Preferred label**: alternative ways used to refer to name

Confusing these three things can cause problems when trying to create a conceptual model. Two things that are genuinely different should have two different names. However, if one thing is given two names when the one thing really is two different preferred labels problems can occur.

Power of Agreement

It is only through deliberate, methodical, rigorous and conscious collaboration, cooperation and coordination by the participants of the financial reporting supply chain that XBRL-based digital financial reporting will work safely, reliably, predictably, repeatedly, effectively, and efficiently. This objective will not be achieved by accident.

Consider the definitions of arbitrary and standard:

- **Arbitrary**: based on random choice or personal whim, rather than any reason or system; depending on individual discretion (as of a judge) and not fixed by law
- **Standard**: used or accepted as normal; something established by authority, custom, convention, law, regulation, or general consent as a model or example

US GAAP contains many, many standard terms. For example, Equity, Assets, Liabilities, etc. The US GAAP XBRL Taxonomy names these terms, providing a standard. A common obstacle to creating a working dictionary of concepts and relations between those concepts is disagreement as to those definition and relations. Agreement by all stakeholders through deliberate, methodical, rigorous and conscious collaboration, cooperation, and coordination can help overcome this obstacle.

Differentiating the Important from the Unimportant

The following terms help one understand the difference between an important nuance and an unimportant negligible difference.

- **Nuance**: a subtle but important difference in or shade of meaning, expression, or sound; a subtle but important distinction or variation
- **Subtle**: so delicate or precise as to be difficult to analyze or describe but important; hard to notice or see but important; not obvious but important
- **Negligible**: so small or unimportant as to be not worth considering; insignificant; so small or unimportant or of so little consequence as to warrant little or no attention

Business professionals can best differentiate important nuances from unimportant negligible differences. They do not do it perfectly and the only real way to make sure things are right is testing and experimentation.

Ontology-like things are about getting the salient aspects of a problem domain right. One needs to take a pragmatic view of the world because it is impossible to describe every single aspect of the real world in machine-readable form. Logical systems only need to represent the important things and serve as a "wireframe" or a "substrate" of reality. Getting bogged down in unimportant, insignificant, or inconsequential details at best serves no purpose, at worst can cause unnecessary complexity and a false sense of comfort.

Difference between Simplistic and Simple

Anyone can create something that is sophisticated and 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. Simple is the ultimate sophistication. Simple is elegant.

- **Simplicity**: Simplicity is "dumbing down" a problem to make the problem easier to solve.
- **Simple**: 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.

Difference between a Requirement and a Policy

Sometimes things are required, other times things are a choice. Yet in other times setting some policy eliminates certain options which could have been previously considered.

- **Policy**: a course or principle of action adopted or proposed by a government, party, business, or individual; definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions
- **Requirement**: a thing that is needed or wanted; something that is essential or that must be done
- **Choice**: an act of selecting or making a decision when faced with two or more possibilities; the act of choosing; the act of picking or deciding between two or more possibilities
- **Option**: a thing that is or may be chosen; the opportunity or ability to choose something or to choose between two or more things

Any time a business professional is presented with an alternative complexity increases because the business professional then must choose between the available alternatives. As the number of choices increases, complexity increases. Choices must be managed. Flexibility when it is not necessary is not a feature, it is a bug.

Best Practices

A **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.

High-fidelity, High-resolution, High-Quality

A general-purpose financial report provides high-fidelity, high-resolution information that is of very high-quality. Consider this scenario:

> Two public companies, A and B, each have knowledge about their financial position and financial performance. They must communicate their knowledge 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 are using a common set of basic logical principles (facts known to be true, deductive reasoning, inductive reasoning, etc.) and common financial reporting standards (i.e. US GAAP, IFRS, etc.), so they should be able to communicate this information fully, so that any inferences which, say, the investor draws from public company A's input should also be derivable by public company A using basic logical principles and common financial reporting standards, and vice versa; and similarly for the investor and public company B.

Let's be clear about the terms we are using and the need for low to zero tolerance for error. Specifically, let's be clear about the following definitions:

- **Reliability** is about getting consistent results each time an activity is repeated.
- **Accuracy** is about identifying the correct target. Accuracy relates to correctness in all details; conformity or correspondence to fact or given quality, condition; deviating within acceptable limits from a standard. Accuracy means with no loss of resolution or fidelity of what the sender wishes to communicate and no introduction of false knowledge or misinterpretation of communicated information.
- **Precision** is the closeness of repeated measurements to one another. Precision involves choosing the right equipment and using that equipment properly. Precise readings are not necessarily accurate. A faulty piece of equipment or incorrectly used equipment may give precise readings (all repeated values are close together) but inaccurate (not correct) results.
- **Fidelity** relates to the exactness or loyal adherence facts and details with which something is copied or reproduced. Fidelity relates to the faithful representation of the facts and circumstances represented within a financial report properly reflect, without distortion, reality. High fidelity is when the reproduction (a financial report) with little

distortion, provides a result very similar to the original (reality of economic entity and environment in which economic entity operates).

- **Integrity** is the quality or condition of being whole or undivided; completeness, entireness, unbroken state, uncorrupt. Integrity means that not only is each piece of a financial report correct but all the pieces of the financial report fit together correctly, all things considered.
- **Resolution** relates to the amount of detail that you can see. The greater the resolution, the greater the clarity.
- **Completeness** relates to having all necessary or normal parts, components, elements, or steps; entire.
- **Correctness** relates to freedom from error; in accordance with fact or truth; right, proper. Consistency relates to being compatible or in agreement with itself or with some group; coherent, uniform, steady. Holding true in a group, compatible, not contradictory.

Differentiating between Objective and Subjective

There is a difference between something that is objective and something that is subjective.

- **Objective**: not influenced by personal feelings or opinions in considering and representing facts; based on facts rather than feelings or opinions; not influenced by feelings; facts are objective.
- **Subjective**: based on or influenced by personal feelings, tastes, preferences, or opinions; based on feelings or opinions rather than facts; relating to the way a person experiences things in his or her own mind; opinions are subjective.
- **Judgment**: the ability to make considered decisions or come to sensible conclusions; an opinion or decision that is based on careful thought; judgment is subjective.

Remember, computers are machines. Computers have no intelligence until they are instructed by humans. Computers only appear smart when humans create standards and agree to do things in a similar manner in order to achieve some higher purpose. It is easy to agree on things that tend to be objective. It is harder to agree where there is subjectivity. It is extremely difficult to impossible to get a machine to exercise judgment. A machine such as a computer can only mimic what humans tell the machine to do via machine-readable information.

Difference between Explicit and Implicit

In the process of agreeing, it is important to understand the difference between what is important and what is unimportant in that process of agreeing. It is likewise important to understand the difference between telling a machine something and requiring the machine to figure something out:

- **Explicit**: Stated clearly and in detail, leaving no room for confusion or doubt; very clear and complete; leaving no doubt about the meaning.
- **Implicit**: Implied though not plainly expressed; understood though not clearly or directly stated.
- **Ambiguous**: Open to more than one interpretation; having a double meaning; able to be understood in more than one way; having more than one possible meaning; not expressed or understood clearly.
- **Derive or Impute**: Assign (a value) to something by inference from the value of the products or processes to which it contributes; to deduce a conclusion about some fact using some other fact or facts and logical reasoning.

Machines do well with information which is explicitly provided. When information is not explicitly provided, software developers either make a choice or have to figure out ways to allow a business professional making use of the software to make a choice. Every time a software developer or business professional has to make an interpretation because something is ambiguous, there is the possibility that some unexpected or incorrect interpretation can be made. Not being explicit causes confusion and turns using ambiguous information into a guessing game.

Multidimensional Logical Model

Logical models help communication and provide a framework for understanding. The multidimensional logical model is a model for understanding information[73]. Every professional accountant works with multidimensional information every day but don't generally realize it.

Just like an electronic spreadsheet has a logical model (workbook, spreadsheet, row, column, cell); a digital financial report has a logical model. The logical model of a digital financial report follows the multidimensional logical model. Here are the high-level pieces of a digital financial report:

- **Fact**: A fact defines a single, observable, reportable piece of information contained within a financial report, or fact value, contextualized for unambiguous interpretation or analysis by one or more distinguishing characteristics. Facts can be numbers, text, or prose.

[73] *Introduction to the Multidimensional Model for Professional Accountants*, http://xbrl.squarespace.com/journal/2016/3/18/introduction-to-the-multidimensional-model-for-professional.html

- **Characteristic**: A characteristic describes a fact (a characteristic is a property of a fact). A characteristic provides information necessary to describe a fact and distinguish one fact from another fact. A fact may have one or many distinguishing characteristics. Aspect is a synonym for characteristic.
- **Fact table**: A fact table is a set of facts which go together for some specific reason. All the facts in a fact table share the same characteristics.
- **Relation**: A relation is how one thing in a business report is or can be related to some other thing in a business report. These relations are often called business rules. There are three primary types of relations (others can exist):
  - **Whole-part**: (functional component) something composed exactly of their parts and nothing else; the sum of the parts is equal to the whole (roll up).
  - **Is-a**: (type or class relation) descriptive and differentiates one type or class of thing from some different type or class of thing; but the things do not add up to a whole.
  - **Computational business rule**: (assertion) Other types of computational business rules can exist such as "Beginning balance + changes = Ending Balance" (roll forward) or "Net income (loss) / Weighted average shares = Earnings per share".
- **Grain**: Grain is the level of depth of information or granularity. The lowest level of granularity is the actual transaction, event, circumstance, or other phenomenon represented in a financial report. The highest level might be a line item on a primary financial statement such as a balance sheet.

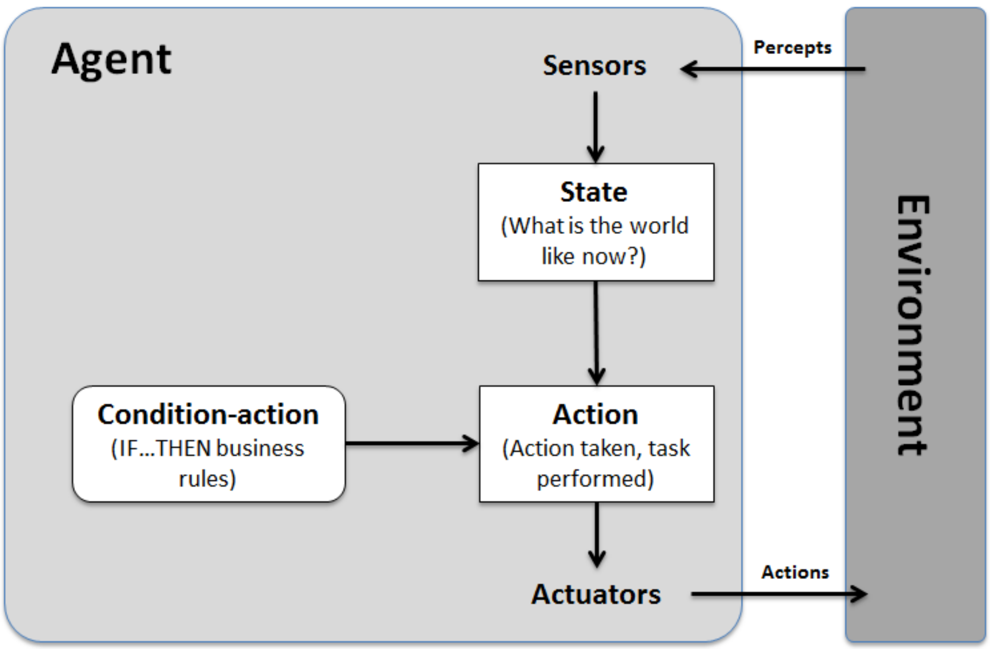
Understanding Intelligent Software Agents

Artificial intelligence is the automation of activities that we associate with human thinking and activities such as decision making, problem solving, learning and so on. An intelligent software agent[74] is software that assists people and acts on their behalf. Intelligent agents work by allowing people to:

- delegate work that they could have done to the agent software,
- perform repetitive tasks,
- remember things you forgot,
- intelligently find, filter and summarize complex information,
- customize information to your preferences,
- learn from you and even make recommendations to you.

[74] *Comprehensive Introduction to Intelligent Software Agents*, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part01_Chapter02.7_ComprehensiveIntroductionToIntelligentSoftwareAgents.pdf

An **agent** is an entity capable of **sensing** the **state** of its **environment** and **acting** upon it based on a set of specified **rules**. An agent performs specific tasks on behalf of another. In the case of software, an agent is a software program. There are many different types of intelligent software agents[75]. The fundamental task of an intelligent agent is to achieve goals or "make goals true".



A simple reflex agent looks up what it should do from a **list of rules** in response to its perception to the environment. This is the algorithm of a simple reflex agent[76]:

Function Simple-Reflex-Agent (percept) returns action

- **persistent**: *rules*, a set of condition-action rules
- *state* <<<< Interpret-Input (*percept*)
- *rule* <<<< (Rule-Match (*state*, *rules*))
- *action* <<<< *rule*. Action
- **return** *action*

The document *Comprehensive Introduction to Intelligent Software Agents*[77] goes into significantly more detail on the topic of intelligent software agents.

[75] Wikipedia, *Intelligent Agent,* Retrieved July 24, 2016; https://en.wikipedia.org/wiki/Intelligent_agent

[76] Hugo Larochelle, *Intelligence Artificielle*, Retrieved July 24, 2016; https://www.youtube.com/watch?v=TUHAVbaBLlg

[77] Charles Hoffman and Rene van Egmond, *Comprehensive Introduction to Intelligence Software Agents*, http://xbrlsite.azurewebsites.net/2017/IntelligentDigitalFinancialReporting/Part01_Chapter02.7_ComprehensiveIntroductionToIntelligentSoftwareAgents.pdf

Categories of Intelligent Software Agent Functionality

The functionality of an intelligent software agent can be classified into groups, or categories:

- **Reactive agent**: A reactive agent is capable of maintaining an ongoing interaction with the environment and responding in a timely fashion to changes that occur in it.
- **Proactive agent**: A proactive agent is capable of taking the initiative; not driven solely by events, but capable of generating goals and acting rationally to achieve them.
- **Deliberative agent**: A deliberative agent symbolically represents knowledge and makes use of mental notions such as beliefs, intentions, desires, choices and so on. This is implemented using a belief-desire-intension model.
- **Hybrid agent**: A hybrid agent is one that mixes some of all the different architectures.

Every intelligent software agent falls into one of those four categories.

Categories of Intelligent Software Agent Sophistication

Intelligent software agents can be grouped as to the level of sophistication offered by the agent:

- **Generic agent**: An agent is anything that perceives an environment through sensors and acts or reacts upon the environment through effectors.
- **Simple reflex agent**: A simple reflex agent looks up what it should do from a list of rules in response to its perception to the environment.
- **Model-based reflex agent**: A model-based reflex agent is the same thing as a simple reflex agent except that a model-based reflex agent has a model of how the environment evolves.
- **Goal-based agent**: A goal-based agent has a goal or set of goals that it actively pursues in accordance with an agenda (so this type of agent is proactive, not just reactive). A goal-based agent has a representation of the current state of the environment and how that environment works. The agent pursues policies or goals that may not be immediately attainable. And so, goal-based agents do not live merely in the moment. These agents consider different scenarios before acting on their environments, to see which action will probably attain a goal. This consideration of different scenarios is called search and planning.
- **Utility-based agent**: A utility-based agent 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 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.

Every intelligent software agent falls into one of those groups in terms of sophistication of functionality offered.

Benefits of an Expert System

Benefits from the use of expert systems include:

- **Reduced costs by using automation**: elimination of routine, boring, repetitive, mundane, mechanical, rote tasks that can be automated
- **Increased uniformity**: consistent answers from the same question or facts; computers are good at performing repetitive, mechanical tasks whereas humans are not; computers do not make mistakes and are good at repeating exactly the same thing each time; performance level is consistent
- **Reduced down-time**: computer based expert systems are tireless and do not get distracted
- **Increased availability**: computer based expert systems are always available simultaneously in multiple places at one time; you get quick response times and can replace absent or scarce experts; convenient
- **Diligence and tenacity**: computers excel at paying attention to detail; they never get bored or overwhelmed and they are always available and will keep doing their job until the task is complete with the same attention to detail
- **Basis for training**: the best practices of the best practitioners can be available to those that are new to and learning about a domain of knowledge
- **Longevity and persistence**: computer based expert systems do not change jobs or retire so knowledge gathered by an organization can remain within that organization
- **Productivity**: computer based expert systems are cheaper that hiring experts and costs can be reduced the same time that quality increases resulting in increased productivity
- **Multiple opinions**: Systems can integrate the view of multiple experts within a system and choose between the preferred view of multiple expert opinions in the same system
- **Objectivity**: computers apply the same inductive and deductive logic consistently; emotion and personal preferences can be eliminated where they should be eliminated; expert systems do not discriminate

- **Easier dissemination of knowledge**: expert systems are software and metadata and therefore once you have that software and metadata reproducing another version is trivial and the incremental cost is extremely low

In a knowledge based or expert system; knowledge is explicitly represented and can be evaluated, knowledge is permanent, knowledge is easily replicated, and the system is consistent. Operating costs of an expert system are low. Financial report creation software of the future will be an expert system which operates similar to how CAD/CAM software for creating blueprints.

Disadvantages of Expert Systems

Everything has advantages and disadvantages. The following can be disadvantages of expert systems:

- **Initial cost**: the initial cost of creating an expert system can be high; the primary cost is for creation of the expert knowledge which is used by the system
- **Maintaining knowledge**: human experts constantly update their knowledge through interaction with other experts, new ideas, common sense, etc.; expert systems have to be maintained to keep knowledge current
- **Garbage in, garbage out**: an expert system is only as good as the machine-readable knowledge which the system uses
- **No common sense**: humans have common sense, expert systems do not
- **Lacks human touch**: expert systems are computer application and have the same characteristics of a computer; they have no compassion, no intuition, cannot exercise real judgment, etc.
- **Inflexibility**: a system, once set up, is inflexible or rather only flexible to the extent that new knowledge is added to the system
- **Restricted**: an expert system usually has expertise in one specific domain of knowledge and is therefore restricted to that specific knowledge

To make expert systems work effectively, disadvantages must be overcome and expert systems should be used to solve problems they are truly capable of solving. Setting the right expectations is important.

Describing a Logical System in Practical and Simple Terms

Logic was invented by Aristotle in the 4th century BCE. Logic is a discipline of philosophy and can serve as a Rosetta Stone that helps business professionals communicate with information technology professionals and knowledge engineers[78]. Logic is a common language that can be agreed upon, understood by all parties, and which therefore enables precise communication.

Logic helps us understand the meaning of statements and to produce new meaningful statements. Logic is the glue that holds strings of statements together and pins down the exact true unambiguous meaning of those statements.

Logic is the process of deducing information correctly[79]; logic is not about deducing correct information. Suppose you were given incorrect information. Your statements can be false but the reasoning behind conclusion sound. Other means are necessary to determine if a statement is true or false.

A **logical system**[80] (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 common models, structures, and statements for capturing meaning or representing a shared understanding of and knowledge in some universe of discourse.

A logical system or logical theory is made up of a set of **models**, **structures**, **terms**, **associations**, **assertions**, and **facts**. In very simple terms,

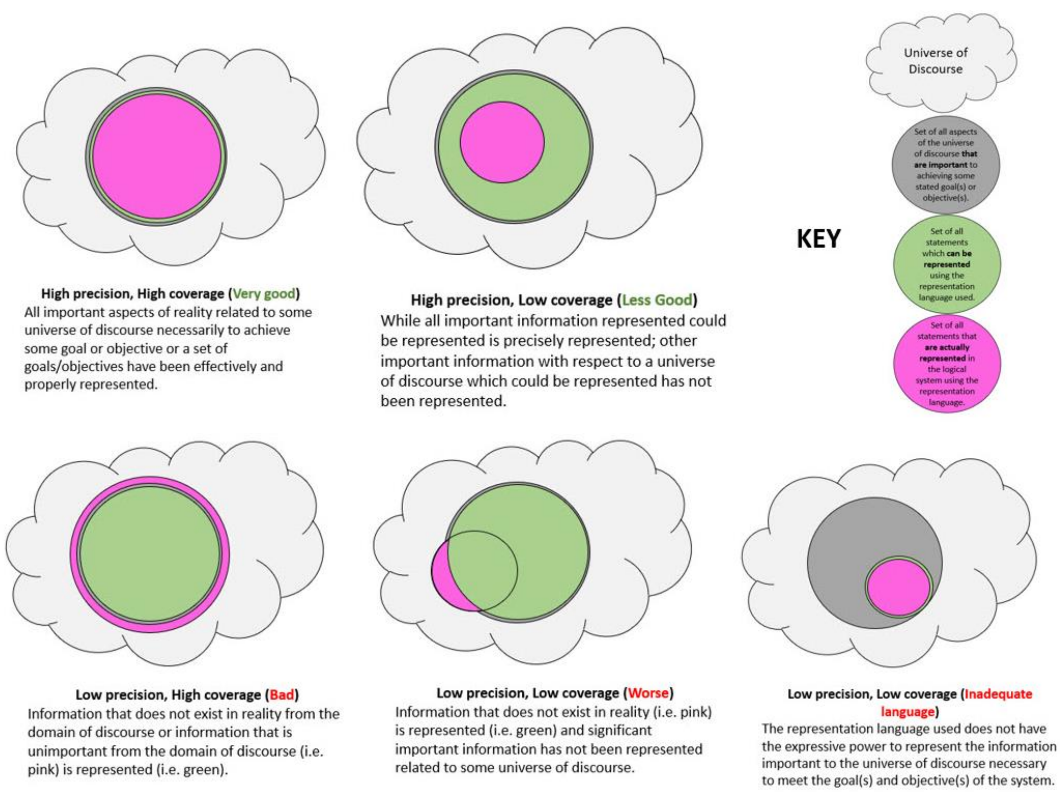
- **Logical theory**: A logical theory is a set of *models* that are consistent with that logical theory.
- **Model**: A model is a set of *structures*. A model is an interpretation of a theory.
- **Structure**: A structure is a set of *statements* which describe the structure. A structure provides context.
- **Statement**: A statement is a proposition, claim, assertion, belief, idea, or fact about or related to the universe of discourse. There are four broad categories of statements:
    - **Terms**: Terms are statements that define ideas used by the logical theory such as "assets", "liabilities", and "equity".

[78] Ronald Fuller, *Business and IT Professionals Should Study Formal Logic*, http://oninfo.info/11-information/56-business-and-it-professionals-should-study-formal-logic
[79] Charles Hoffman, CPA, *Constructing a Chain of Reasoning*, http://xbrl.squarespace.com/journal/2019/9/26/constructing-a-chain-of-reasoning.html
[80] Charles Hoffman, CPA, *Explanation of a Financial Report Logical System in Simple Terms*, http://xbrl.squarespace.com/journal/2019/11/1/explanation-of-a-financial-report-logical-system-in-simple-t.html

- **Associations**: Associations are 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".
- **Assertions**: Assertions are statements that describe what tend to be 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 statements about the numbers and words that are provided by an economic entity within their financial report. For example, "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.

A logical system is said to be **consistent** if there are no contradictions or inconsistencies with respect to the statements made by the logical system.

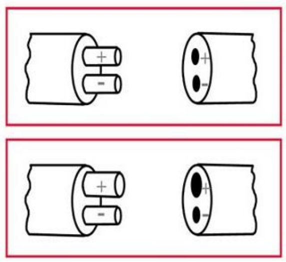
A logical system can have high to low **precision** and high to low **coverage**. *Precision* is a measure of how precisely the information within a logical system has been represented as contrast to reality for the universe of discourse. *Coverage* is a measure of how completely information in a logical system has been represented relative to the reality for a universe of discourse.



Poka-yoke (Mistake proofing)

Poka-yoke is a technique used to prevent mistakes through smarter design. Poka-yoke[81] is a Japanese term that means "mistake-proofing". A poka-yoke is any mechanism consciously added to a process that helps an equipment operator avoid mistakes. Its purpose is to eliminate defects by preventing, correcting, or drawing attention to human errors as the errors occur.

For example, consider the graphic[82] below. You want someone to insert a plug into the receptacle such that positive and negative match up; inadvertently reversing this would have catastrophic consequences. In the top graphic, notice that it is possible to make a mistake but in the bottom a mistake would be impossible because of the size differences in the positive and negative receptacle and plug.



Smart design means less user errors. Blocks are a mechanism for implementing poka-yoke, or mistake proofing XBRL-based information. Primitive object structure, mechanical relations, mathematical relations, logical relations, and even some accounting relations must make sense relative to other primitive objects. Blocks and the structured nature of XBRL make implementing these mistake proofing techniques possible with financial report creation software.

Double-entry accounting is a type of poka-yoke mechanism used by professional accountants. The first recorded use of double-entry accounting was in 1211 AD by a bank in Florence[83]. The foundational basis of double-entry accounting is straightforward. Quoting David Ellerman from his paper *The Math of Double-Entry Bookkeeping: Part I (scalars)*[84]:

"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."

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[81] Wikipedia, *Poka-yoke*, https://en.wikipedia.org/wiki/Poka-yoke
[82] Process Exam, *Six Sigma Tools - Poka Yoke*, http://www.processexam.com/six-sigma-tools-poka-yoke
[83] 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
[84] David Ellerman, *The Math of Double-Entry Bookkeeping: Part I (scalars)*, http://www.ellerman.org/the-math-of-double-entry-bookkeeping-part-i-scalars/

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. Double-entry accounting is smart design.

Excessive Process Automation

Don't overdo it with process automation. First, only processes that are working effectively should be automated. Automating a process that is not working makes no sense. Second, take an incremental approach to automating processes.

Tesla's CEO Elon Musk said, "Excessive automation at Tesla was a mistake." In the 1980s, General Motors wasted billions of dollars in a largely fruitless effort to automate car product. A lot of mistakes like these are made only to be repeated in the future because people are no aware of the history.

Automation works best when it is applied incrementally to a process that is already working smoothly and effectively.

Experiencing the Benefits of Ontology-like Things

The best way to put all the pieces together in your mind is to experience the benefits of ontology-like things provided by a software application. We have created a number of working proof of concepts to help provide you with this experience so that you can see the benefits for yourself first hand.

Pesseract[85] is a software application that is used for creating XBRL-based financial reports. Currently, Pesseract can best be described as a working proof of concept. It cannot yet be considered a commercial product. But Pesseract is very good at helping professional accountants understand XBRL-based digital financial reporting[86].

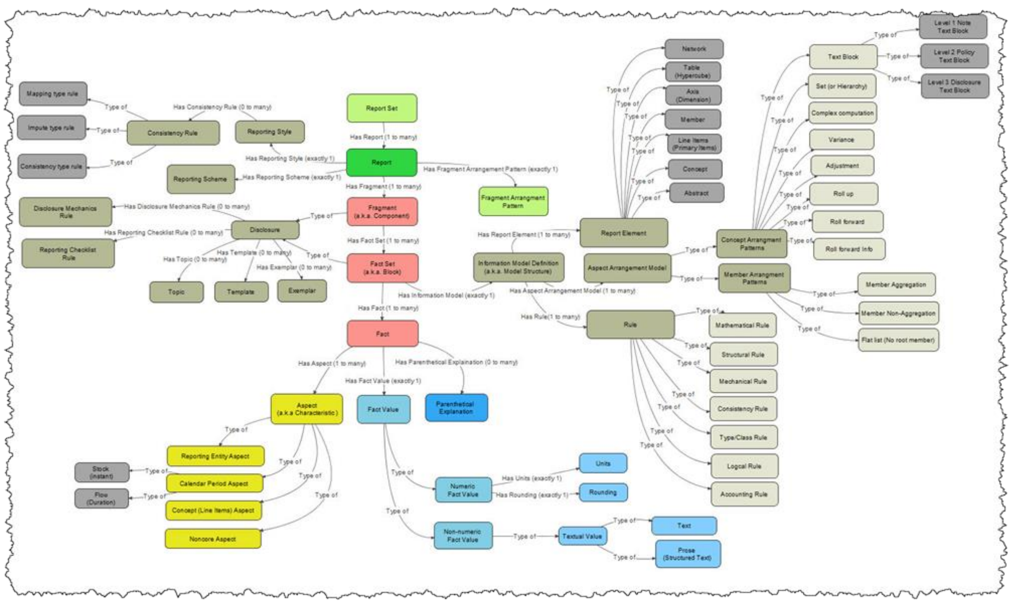
Pesseract automatically configures itself for a specific reporting scheme[87] using provided machine-readable metadata for the reporting scheme. The metadata helps the software application understand a financial report and assists professional accountants when working

[85] Pesseract, http://pesseract.azurewebsites.net/
[86] Understanding Digital Financial Reporting Using Pesseract, http://xbrl.squarespace.com/journal/2018/10/14/understanding-digital-financial-reporting-using-pesseract.html
[87] Comparison of Financial Reporting Scheme High Level Concepts, http://xbrlsite.azurewebsites.net/2018/Library/ReportingSchemes-2018-12-30.pdf

with such reports. Today, metadata is provided for six financial reporting schemes[88]: US GAAP[89], IFRS[90], IPSAS[91], FRF for SMEs[92], MINI[93], and XASB[94]. If you are an accountant you probably now about the first three reporting schemes buy have likely never heard of the fourth, XASB. XASB is a contrived reporting scheme that is used for testing and prototyping. It was created to be small but comprehensive.

To support four different reporting schemes the notion of a profile[95] was created to manage differences in the way that regulators, standards setters, and others architected their reporting scheme.

All six reporting schemes use the same financial report framework[96]. What the financial report framework does is provide an ontology-like thing which describes the mechanics and structure of a financial report.



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[88] Charles Hoffman, CPA, *Modern Approach to Creating a Financial Reporting Scheme*, http://xbrl.squarespace.com/journal/2019/12/19/modern-approach-to-creating-a-financial-reporting-scheme.html
[89] US GAAP, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Home.html
[90] IFRS, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/ifrs/documentation/Home.html
[91] IPSAS (International Public Sector Accounting Standards XBRL Taxonomy Prototype Project), http://xbrlsite.azurewebsites.net/2020/reporting-scheme/ipsas/documentation/Home.html
[92] FRF for SMEs, http://xbrlsite.azurewebsites.net/2016/conceptual-model/reporting-scheme/frf-sme/documentation/Home.html
[93] MINI, http://xbrlsite.azurewebsites.net/2019/Prototype/mini/documentation/Home.html
[94] XASB, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/xasb/documentation/Home.html
[95] XBRL-based Digital Financial Reporting Profiles and General Business Reporting Profile, http://xbrlsite.azurewebsites.net/2018/Library/Profiles-2018-10-22.pdf
[96] Open Source Framework for Implementing XBRL-based Digital Financial Reporting, http://xbrlsite.azurewebsites.net/2019/Framework/FrameworkEntitiesSummary.html

Ultimately, the existing framework will be changed to the forthcoming OMG Standard Business Report Model (SBRM)[97] framework.

Information about a reporting scheme is represented in machine readable form using this framework. That information is then leveraged by software applications such as Pesseract.

The base financial reporting scheme information is generally provided by some authority using the XBRL format. XBRL taxonomies are provided by the Financial Accounting Standards Board (FASB) for US GAAP[98] and by the International Financial Reporting Standards (IFRS) Foundation for IFRS[99].

As is explained in the document *Demystifying the Role of Ontologies in XBRL-based Digital Financial Reporting*[100], today financial reporting related XBRL taxonomies tend to be informal "pick lists" better suited for humans reading the taxonomy than for machines to make use of them. As such, the financial reporting taxonomies are supplemented with additional information to make them better suited for use by software applications.

Today, supplemental metadata in the form of an ontology-like thing is provided for US GAAP, IFRS, IPSAS, and XASB reporting schemes. The most comprehensive and complete sets of metadata are provided for the US GAAP and XASB reporting schemes. All of this metadata is provided in a temporary manner[101] until a more formal model becomes available such as the OMG Standard Business Report Model (SBRM)[102].

Two additional formats for providing a financial reporting ontology-like thing are being tested and prototyped. For now, both prototypes are for the US GAAP financial reporting scheme. Ultimately, both human-readable and machine-readable information will be provided for each financial reporting scheme in a manner to be determined by what is learned from creating these prototypes.

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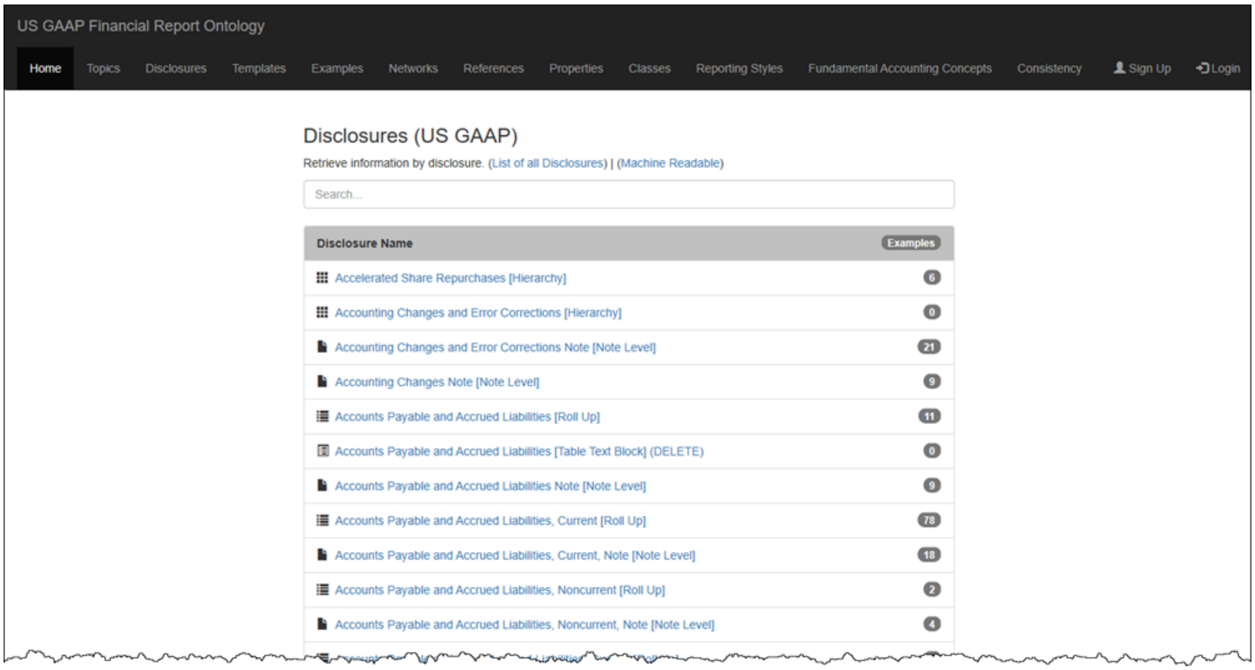
[97] Charles Hoffman, CPA, *OMG Standard Business Report Model (SBRM) Initial Submission Information*, http://xbrl.squarespace.com/journal/2019/11/15/omg-standard-business-report-model-sbrm-initial-submission-i.html
[98] Reporting Using US GAAP, http://xbrl.squarespace.com/reporting-using-us-gaap/
[99] Digital Financial Reporting using IFRS, http://xbrl.squarespace.com/reporting-using-ifrs/
[100] Charles Hoffman, CPA, *Demystifying the Role of Ontologies in XBRL-based Digital Financial Reporting*, http://xbrlsite.azurewebsites.net/2019/Library/DemystifyingOntologies.pdf
[101] Conceptual Model of a Digital Financial Report, http://xbrl.squarespace.com/conceptual-model/
[102] OMG and the Standard Business Report Model (SBRM), http://xbrl.squarespace.com/journal/2019/6/25/object-management-group-and-the-standard-business-report-mod.html

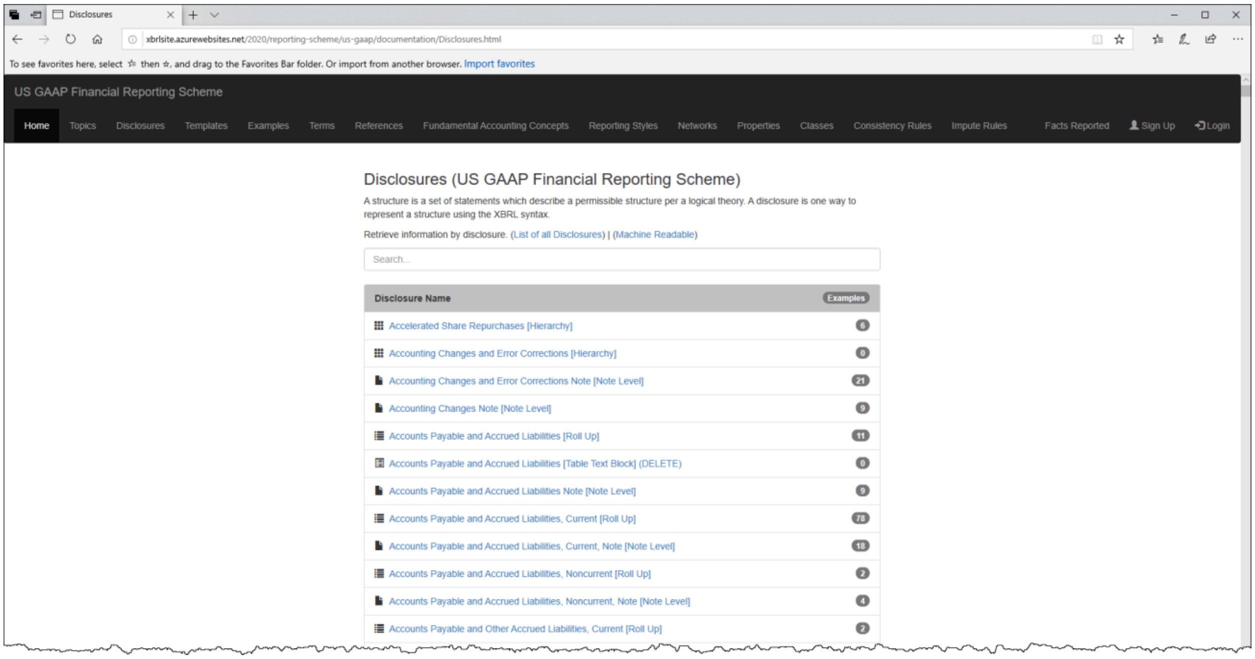
Both prototypes help to demonstrate the benefits of leveraging the functional components defined by the financial reporting framework[103]. As an example, note the functionality provided by the notion of a Topic, Disclosure, Template, and Exemplar.

Here is the first prototype[104]. This prototype demonstrates some fundamental search capabilities and a very clean and easy to understand user interface:



Here is the subsequent prototype[105]. This prototype provides a different user interface format and some prototype report element searching and filtering capabilities:

[103] Charles Hoffman, CPA, *Leveraging Functional Components for XBRL-based Digital Financial Reporting*, http://xbrlsite.azurewebsites.net/2019/Library/LeveragingFunctionalComponents.pdf
[104] First prototype, http://xbrlsite.azurewebsites.net/2019/Prototype/New/Disclosures.html
[105] Subsequent prototype, http://xbrlsite.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Disclosures.html



But the absolute best way of experiencing the benefits provided by the ontology-like things for a reporting scheme is to use Pesseract. The Pesseract software application will help you understand what financial reporting could possibly look like in the future[106].

Conclusion

Understanding how computers work and understanding the techniques that can be used to control a computer can enable you to get a computer to perform useful work are key to understanding the real capabilities of software driven by artificial intelligence. Ontology-like things provided the knowledge that will literally supercharge that software.

But don't make the mistake of believing that you can take short cuts. There are no short cuts. It is hard to get computers to perform work. The benefits are real and very soon more and more software will become available which will help professional accountants recognize those benefits.

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106 *Understanding Digital Financial Reporting using Pesseract*, http://xbrl.squarespace.com/journal/2018/10/14/understanding-digital-financial-reporting-using-pesseract.html

Professional accountants will need to understand how to create XBRL-based financial reports effectively[107]. Professional accountants will need to understand how to create and audit strategy to audit XBRL-based financial reports[108].

For More Information Related to Financial Reports

For more examples see the *Summary of Human Readable Renderings*[109] provided for a number of reporting schemes.

For a self-guided tour of an XBRL-based report, please see *Self Guided Tour of XBRL-based Financial Report*[110].

Suggested Reading

The following books are extremely helpful in trying to knowledge engineering ideas. Anyone who wants to understand knowledge engineering in more detail should consider reading the following books:

- ***Data and Reality***[111], by William Kent: (162 pages) While the first and last chapters of this book are the best, the entire book is very useful. The primary message of the Data and Reality book is in the last chapter, Chapter 9: Philosophy. The rest of the book is excellent for anyone creating a taxonomy/ontology and it is good to understand, but what you don't want to do is get discouraged by the detail and then miss the primary point of the book. The goal is not to have endless theoretical/philosophical debates about how things could be. The goal is to create something that works and is useful. A shared view of reality. That enable us to create a common enough shared reality to achieve some working purpose.
- ***Everything is Miscellaneous***[112], by David Wenberger: (277 pages) This entire book is useful. This is very easy to read book that has two primary messages: (1) Every classification system has problems. The best thing to do is create a flexible enough

[107] 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
[108] Charles Hoffman, CPA, *Auditing XBRL-based Financial Reports*, http://xbrl.squarespace.com/journal/2019/10/17/auditing-xbrl-based-financial-reports.html
[109] *Summary of Human Readable Renderings*, http://xbrl.squarespace.com/journal/2019/3/23/summary-of-human-readable-renderings.html
[110] *Self Guided Tour of XBRL-based Financial Report*, http://xbrl.squarespace.com/journal/2019/4/16/self-guided-tour-of-xbrl-based-financial-reports.html
[111] See, http://xbrl.squarespace.com/journal/2014/7/28/data-and-reality-what-is-the-purpose-of-sec-xbrl-financial-f.html
[112] See, http://xbrl.squarespace.com/journal/2011/1/31/us-gaap-taxonomy-build-it-to-allow-reoganization.html

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. (2) The big thing is that this book explains the power of metadata. First order of order, second order of order, and third order of order.

- ***Models. Behaving. Badly.***[113], by Emanual Derman: (231 pages) The first 100 pages of this book is the most useful. If you read the *Financial Report Semantics and Dynamics Theory*, you got most of what you need to understand from this book. But the book is still worth reading. It explains extremely well how it is generally one person who puts in a ton of work, figures something out, then expresses extremely complex stuff in terms of a very simple model and then thousands or millions of people can understand that otherwise complex phenomenon.
- ***Systematic Introduction to Expert Systems: Knowledge Representation and Problem Solving Methods***[114], by Frank Puppe: (350 pages) The first three chapters of this book are an excellent introduction to expert systems, about 25 pages, and is easily understandable to a business professional. The second section of this book explains how expert systems work and the moving pieces of expert systems. The last to sections get technical, but are still understandable, and provide what amounts to an inventory of problem solving approaches and how to best implement those approaches in software.
- ***Ontology Engineering***[115], by Elisa Kendall and Deborah McGuinness: (120 pages) This is a knowledge engineering text book that is fairly easy for a business professional to read. The two best chapters are Chapter 1 – Foundation and Chapter 4 – Terminology.
- ***Ontology for the Twenty First Century: An Introduction with Recommendations***[116], by Andrew D. Spear: (132 pages) The introduction first 45 pages are the best. This can be challenging to make your way through but if you really want to understand all of the issues in creating useful ontologies; reading this is worth the effort.

Feel you want even more details? You can get all you want of my lab notes on my blog:

http://xbrl.squarespace.com/blog-archive/

[113] See, http://xbrl.squarespace.com/journal/2014/7/20/updated-financial-report-semantics-and-dynamics-theory.html
[114] See, http://xbrl.squarespace.com/journal/2015/7/15/understanding-expert-systems-applicability-to-financial-repo.html
[115] See, https://www.amazon.com/Ontology-Engineering-Synthesis-Lectures-Semantic/dp/1681733080
[116] See, http://ifomis.uni-saarland.de/bfo/documents/manual.pdf