

Computational Professional Services

Making computational accounting, reporting, auditing, analysis, law, and regulation to work for business

By Charles Hoffman, CPA (Charles.Hoffman@me.com)

September 10, 2020 (DRAFT)

“The difficulty lies not so much in developing new ideas as in escaping from old ones.”

*John Maynard Keynes*¹

“If I had asked people what they wanted, they would have said faster horses.” Henry Ford²

Executive summary:

- Structured information, artificial intelligence, knowledge graphs, digital distributed ledgers, and other such technologies offer unprecedented opportunities to more efficiently, more cost effectively, and to deliver professional services in a timelier manner and in new ways.
- There is not necessary only one way to succeed with these new technologies; however, there are good practices and best practices and there are methods that are proven to work effectively.
- Clearly, for computational professional services to be useful, it actually needs to work, be reliable, be predictable, and provide benefits in terms of better, faster, or cheaper professional services offerings.
- XBRL-based digital financial reporting offers a way to think about computational professional services related to financial accounting, reporting, auditing, and analysis.

¹ Good Reads, <https://www.goodreads.com/quotes/5099424-the-difficulty-lies-not-so-much-in-developing-new-ideas>

² Good Reads, <https://www.goodreads.com/quotes/15297-if-i-had-asked-people-what-they-wanted-they-would>

This document is inspired by the excellent paper by Michael Genesereth of Stanford University's Center for Legal Informatics, *Computational Law: The Cop in the Backseat*³. In that paper, the author defines *computational law* as:

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

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

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

I have briefly mentioned computational law⁴, computational audit⁵, computational economics⁶, and computational regulation⁷ (a.k.a. algorithmic regulation⁸) on my blog. I would include each within the larger bucket of **computational professional services**. There are likely other business domains that might fit. But what exactly does “computational professional services” mean and how do you get it to actually work.

That is what is covered within this document. Computational professional services is exemplified by what the Data Coalition calls “smart regulation⁹” or what others call “algorithmic regulation¹⁰”. Others use different terms. For example, Craig Lewis, Chief Economist and Director of the Division of Risk, Strategy, and Financial Innovation (RiskFin) at the SEC used the

³ Michael Genesereth, Stanford University's Center for Legal Informatics, *Computational Law: The Cop in the Backseat*, <http://logic.stanford.edu/complaw/complaw.html>

⁴ Computational Law, <http://xbrl.squarespace.com/journal/2020/8/24/computational-law.html>

⁵ Computational Audit, <http://xbrl.squarespace.com/journal/2020/8/25/computational-audit.html>

⁶ Computational Economics, <http://xbrl.squarespace.com/journal/2020/8/31/computational-economics.html>

⁷ Computational Regulation, <http://xbrl.squarespace.com/journal/2020/9/1/computational-regulation.html>

⁸ Tim O'Reilly, *Open Data and Algorithmic Regulation*, <https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/>

⁹ Smart Regulation Graphic Show the Big Picture, <http://xbrl.squarespace.com/journal/2012/11/12/smart-regulation-graphic-shows-the-big-picture.html>

¹⁰ Tim O'Reilly, *Open Data and Algorithmic Regulation*, <https://beyondtransparency.org/chapters/part-5/open-data-and-algorithmic-regulation/>

term “robo cop”. We will standardize on the term computational professional services for this document.

Computational

Let me first start by explaining what I mean by computational. Per Wikipedia, a **computation**¹¹ is defined as:

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

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

Per Wikipedia (paraphrasing), **algorithm**¹² is defined as:

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

Computational logic¹³ is the use of logic to perform or reason about computation. Logic is used to define the steps and tasks. Logic is a set of principles that forms a framework for correct reasoning. We will dive into logic a little later.

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

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

¹¹ Wikipedia, *Computation*, <https://en.wikipedia.org/wiki/Computation>

¹² Wikipedia, *Algorithm*, <https://en.wikipedia.org/wiki/Algorithm>

¹³ Wikipedia, *Computational Logic*, https://en.wikipedia.org/wiki/Computational_logic

For additional and more information on computational and how computational systems are implemented using machines please see Turing Machine¹⁴ and the Church-Turing Thesis¹⁵.

Professional Services

For completeness I want to provide a definition for **professional services**. Again, Wikipedia offers a good definition¹⁶:

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

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

Rearranging Abstract Symbols

Accounting, reporting, auditing, and analysis have a lot to do with professional accountants “rearranging abstract symbols”. This is what I mean. In his book *Saving Capitalism*¹⁷, Robert Reich describes three categories that all modern work/jobs fit into:

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

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

¹⁴ Wikipedia, Turing Machine, https://en.wikipedia.org/wiki/Turing_machine

¹⁵ Wikipedia, Church-Turing Thesis, https://en.wikipedia.org/wiki/Church%E2%80%93Turing_thesis

¹⁶ Wikipedia, Professional Services, https://en.wikipedia.org/wiki/Professional_services

¹⁷ Robert Reich, *Saving Capitalism*, page 204-206, <https://www.amazon.com/Saving-Capitalism-Many-Not-Few/dp/0345806220>

“In essence this work is to **rearrange abstract symbols** using a variety of analytic and creative tools - mathematical algorithms, legal arguments, financial gimmicks, scientific principles, powerful words and phrases, visual patterns, psychological insights, and other techniques for solving conceptual puzzles. Such manipulations improve efficiency- accomplishing tasks more accurately and quickly-or they better entertain, amuse, inform, or fascinate the human mind.”

Shelly Palmer breaks work tasks down in another way¹⁸. He points out that almost every human job requires us to perform some combination of the following four basic types of tasks:

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

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

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

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

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

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

¹⁸ Shelly Palmer, *The 5 Jobs Robots Will Take Last*, <https://www.linkedin.com/pulse/5-jobs-robots-take-last-shelly-palmer>

Symbolic Systems

A **symbolic system**¹⁹ is essentially a system built with symbols such as natural language, programming languages, mathematics, or formal logic. An interesting thing about such systems is that symbolic systems are understandable by both *humans* and by *computers*.

Interestingly, Stanford University has a popular undergraduate and graduate degree offering in symbolic systems²⁰.

Using financial accounting and reporting as an example; there is nothing natural about double entry bookkeeping²¹, the accounting equation²², the accounting ledger²³, the general purpose financial report²⁴, the spreadsheet²⁵, or the many other artifacts of accounting, reporting, auditing, and analysis²⁶. All of these are tools and symbolic systems invented by man in order to help enable commerce. Arguably, without these accounting tools enterprises such as global multinational corporations would never be able to exist.

Today, in the fourth industrial era²⁷, in this information age²⁸, it is possible to improve upon many of the tasks and processes involved with accounting, reporting, auditing, and analysis of financial information; improving quality, reducing cost, or performing this work faster. The fourth industrial revolution allows for us to use computers, the internet, digital distributed ledgers, structured information, and artificial intelligence to perform these important tasks and processes that keep global commerce moving in better and more efficient ways. Things like “ten finger integration” (i.e. rekeying of information) can be reduced or perhaps even eliminated altogether. This will allow professional accountants to focus on more important and higher value added tasks that cannot be performed by computers.

¹⁹ Symbolic Systems, <http://xbrl.squarespace.com/journal/2020/8/26/symbolic-systems.html>

²⁰ Stanford University, Symbolic Systems Program, <https://symsys.stanford.edu/about/span-dig-deep-solve-complex-problems>

²¹ The Math of Double Entry Bookkeeping, <http://xbrl.squarespace.com/journal/2019/11/4/the-mathematics-of-double-entry-bookkeeping.html>

²² Accounting Equation, <http://xbrl.azurewebsites.net/2020/master/ae/index.html>

²³ Charles Hoffman and Andrew Noble, Introduction to the Fact Ledger, <http://xbrl.azurewebsites.net/2018/Library/IntroductionToTheFactLedger.pdf>

²⁴ Need for an Alternative to the General Purpose Financial Report, <http://xbrl.squarespace.com/journal/2015/10/28/need-for-digital-alternative-to-general-purpose-financial-st.html>

²⁵ Understanding the Semantic Spreadsheet, <http://xbrl.azurewebsites.net/2020/Library/UnderstandingSemanticSpreadsheets.pdf>

²⁶ Essence of Accounting, <http://xbrl.azurewebsites.net/2020/Library/EssenceOfAccounting.pdf>

²⁷ Adapting to Changes Caused by Fourth Industrial Revolution, <http://xbrl.squarespace.com/journal/2019/8/4/adapting-to-changes-caused-by-the-fourth-industrial-revoluti.html>

²⁸ Wikipedia, *Information Age*, https://en.wikipedia.org/wiki/Information_Age

Computers

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

Strengths of Computers

Computers seem to perform magic. How computers do what they do tends to be a mystery to many people. But computers are simple machines that follow very specific instructions. The strengths of computers can be summarised as follows. Computers can:

- store information
- retrieve information
- process stored information
- make information accessible to individuals or other machines or software

Obstacles to Using Computers

The accounting profession is yet to fully leverage the strengths of computers mainly due to the following general obstacles that tend to get in the way:

- accountants use different terminologies to refer to exactly the same thing
- accountants differ in their understanding and interpretation of accounting standards
- accountants don't understand technologies' limitations
- IT professionals use different technology stacks and languages to achieve the same result
- IT and business professionals have an oversimplified view of accounting

Fundamentally, computers are “dumb beasts” that have to be led by the hand like you lead a baby.

Understanding what Computers Cannot Do

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

- Intuition
- Creativity
- Innovation
- Improvising
- Exploration

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

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

Knowledge-based Systems

The better the capability of a system to represent knowledge²⁹, the better the ability for a software application to read and process that knowledge and perform useful work for the user of the system.

- **A dictionary** would be a simple flat inventory of terms with no relations.
- **A thesaurus** would document some relations between broader and narrower terms. This is more useful than a simple dictionary.
- **A taxonomy** provides descriptions and a limited amount of structure generally in the form of one hierarchy. This is more useful than a thesaurus. A taxonomy is an outcome from knowledge mapping and structuring processes. A taxonomy is a hierarchical classification which helps users understand how explicit knowledge can be grouped and categorized.
- **An ontology** is a model that tends to provide descriptions and multiple structures and therefore tends to have more than one hierarchy. For example, a set of taxonomies which explicitly differentiate types of relations or associations between terms could constitute an ontology.
- **A logical theory** is a set of models (ontology-like things³⁰) that are consistent with permissible per the logical theory. A logical theory provides way of thinking about a domain by means of deductive reasoning to derive logical consequences of the theory.

²⁹ YouTube.com, *Taxonomies, Ontologies, and Knowledge Graphs, Oh My!*, https://youtu.be/3KA_Dcb8Ns

³⁰ Enhanced Description of Ontology-like Thing, <http://xbrl.squarespace.com/journal/2019/7/19/enhanced-description-of-ontology-like-thing.html>

I have created a logical theory that describes the mechanical aspects and dynamics of a financial report³¹. But to get a knowledge-based system to work, you have to put knowledge into that system. So, what exactly constitutes a knowledge-based system?

Components of a Knowledge-based System

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

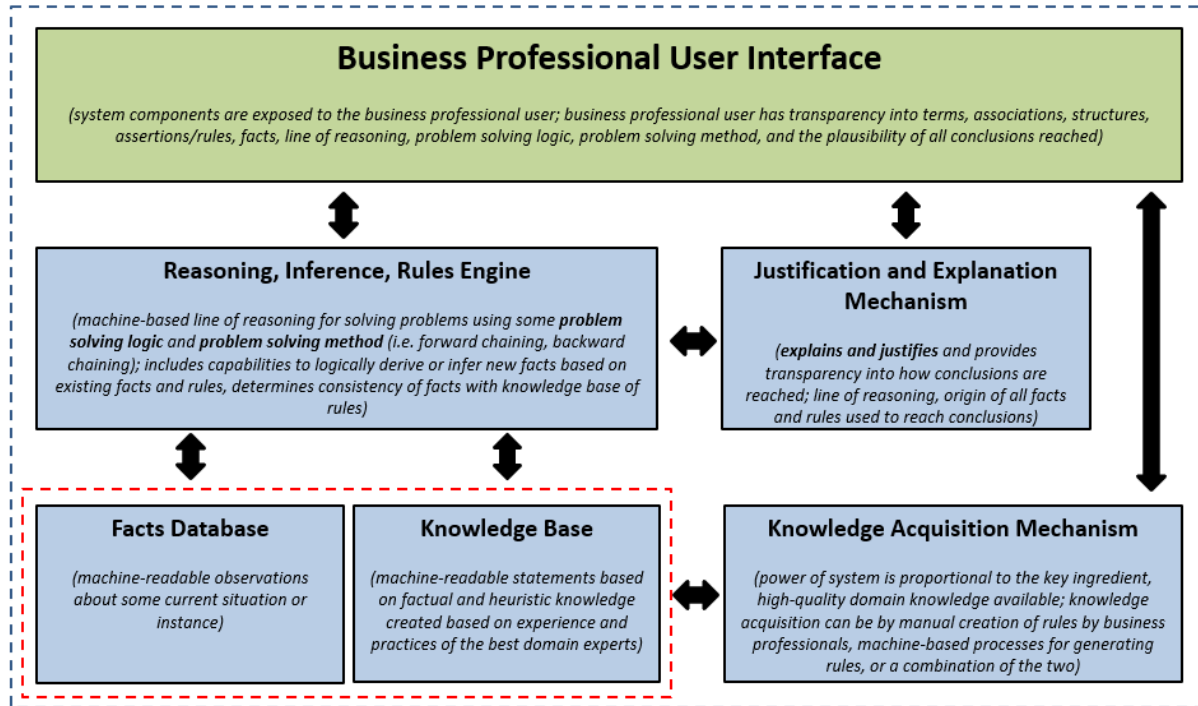
“A knowledge-based system is a computer program that reasons and uses a knowledge base to solve complex problems.”

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

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

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

³¹ *Logical Theory Describing Financial Reports*,
<http://www.xbrlsite.com/2020/Theory/LogicalTheoryDescribingFinancialReport.pdf>



The following describes each of those components:

- **Knowledge acquisition mechanism:** Somehow knowledge needs to be acquired and put into the knowledge-based system.
- **Knowledge base:** Somehow the knowledge acquired needs to be stored in machine-readable form such that it can be used by the system.
- **Fact database:** Similarly, facts need to be stored in machine-readable form such that they can be used by the system.
- **Reasoning, inference, rules engine:** Some rules engine is necessary to process the knowledge and facts. Deductive reasoning is essential; inductive reasoning is a nice-to-have.
- **Justification and explanation mechanism:** Nothing in the system should be a black box. Users of the system must be able to understand the origin of information (providence) and there needs to be an audit trail to understand every decision made and the reasoning behind the system.
- **Business professional user interface:** Business professionals need to interact with the system to be able to perform work on their terms. Technical complexity must be buried deep within the application, business professionals don't care about technical details. Domain complexity is what users should be working with.

Acquiring Knowledge

There are two general approaches to acquiring knowledge to store and then leverage within a knowledge base:

1. **Pattern-based approach:** Let the computer work it out by using AI, machine learning or other approaches. This means, feed the computer a load of data and let it figure out the patterns. (i.e. machine learning)
2. **Rule based approach:** Tell the computer what the knowledge is. Accountants and auditors are highly trained and have the knowledge in their head. All we need is a way of capturing that knowledge and storing it in a knowledge base.

It is not an either-or question. But option 2 needs to be prioritised because it will provide the foundation for AI and machine learning to build on. Machine learning excels where there is a high tolerance for error. There is an extremely low tolerance for error in financial accounting, reporting, auditing, and analysis.

A knowledge-based system draws upon the knowledge of human experts, i.e. accountants and auditors. High-quality curated knowledge can supercharge artificial intelligence application. The more knowledge in the knowledge base, the more the knowledge-based system can do.

Knowledge Graph

Wikipedia defines a knowledge graph³² as a knowledge base that uses a graph-structured data model or topology to integrate data. *The Knowledge Graph Cookbook: Recipes that Work*³³ has a very approachable explanation of knowledge graphs.

Effectively, XBRL is an approach to representing information in the form of a knowledge graph. Other approaches include RDF+OWL+SHACL, PROLOG, and graph databases. An XBRL-based financial report is a knowledge graph³⁴.

From Data to Information to Knowledge

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

³² Wikipedia, *Knowledge Graph*, https://en.wikipedia.org/wiki/Knowledge_graph

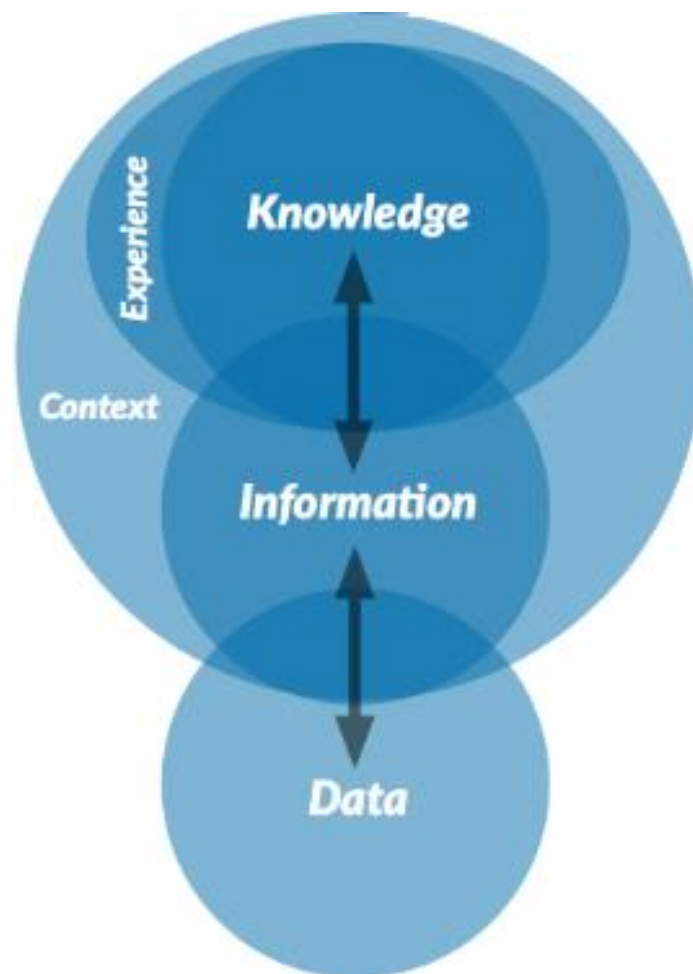
³³ Andreas Blumauer and Helmut Nagy, *The Knowledge Graph Cookbook: Recipes that Work*, <https://www.amazon.com/Knowledge-Graph-Cookbook-Andreas-Blumauer/dp/3902796707>

³⁴ Understanding Financial Report Knowledge Graph, <http://xbrl.squarespace.com/journal/2021/6/18/understanding-financial-report-knowledge-graph.html>

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

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

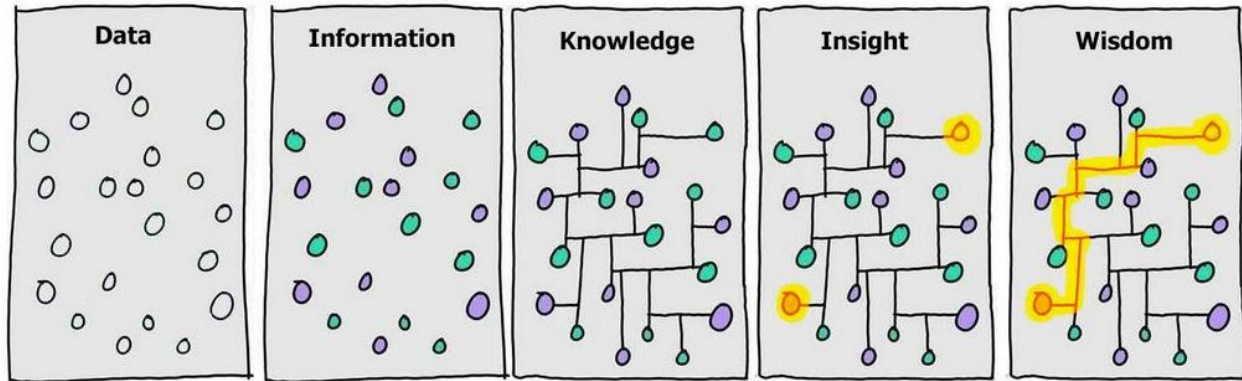
The following graph created by Shawn Riley shows the important to understand differences between data, information, and knowledge³⁵.



³⁵ Shawn Riley, *Machine Learning versus Machine Understanding*, <https://www.linkedin.com/pulse/machine-learning-vs-understanding-shawn-riley/>

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

Here is another graph that helps one understand the difference between data, information, knowledge, insight, and wisdom³⁶:



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

In my popular video, *How XBRL Works*³⁷, I try and explain the difference between information structured for presentation and information structured for meaning. That video is worth watching. But I want to expand that explanation to include the notions of “machine-readability”, “machine-understandable”, and “machine-interpretable”. This spectrum will help you dial in your understanding of the capabilities of computers. If you want all of the details for the examples provided below, please see the SFAC 6 Elements of Financial Statements³⁸ representation.

Machine-readable

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

³⁶ Tumblr, Information vs Knowledge, <https://informationversusknowledge-blog.tumblr.com/>

³⁷ YouTube.com, How XBRL Works, <https://www.youtube.com/watch?v=nATJBPOiTxM>

³⁸ SFAC 6 Representation, <http://xbrlsite.azurewebsites.net/2020/master/sfac6/>

Likewise, even an XBRL-based report is machine-readable but the information contained within the report is not understandable to the computer. Here is a screenshot of a small XBRL-based report³⁹:

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

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

Machine-understandable

While a computer may not understand the meaning of the information, there are some things that the computer does understand. A machine can take the same information shown above and turn it into this⁴⁰:

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

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

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

³⁹ SFAC 6 Representation, Machine Readable, <http://xbrlsite.azurewebsites.net/2020/master/sfac6/instance.xml>

⁴⁰ SFAC 6 Representation, Human Readable, <http://xbrlsite.azurewebsites.net/2020/master/sfac6/evidence-package/contents/Rendering-N1-RE8.html>

Machine-Interpretable

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

So, for example, if you provide the understanding that “If the value of comprehensive income is less than \$5,000; then SELL the company to remove the company from your investment portfolio,” because you have knowledge (i.e. you believe) that companies with comprehensive income of less than \$5,000 are not good investments.

Rules

The Merriam-Webster dictionary defines anarchy⁴¹ as “a situation of confusion and wild behavior in which the people in a country, group, organization, community, etc., are not controlled by rules or laws.” Rules prevent information anarchy⁴².

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

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

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

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

⁴¹ Anarchy definition, Merriam-Webster, <http://www.merriam-webster.com/dictionary/anarchy>

⁴² *Understanding that Business Rules Prevent Anarchy*, <http://xbrl.squarespace.com/journal/2016/7/15/understanding-that-business-rules-prevent-anarchy.html>

“Rules as Code” (i.e. Machine-readable Rules)

In his Ted Talk, Jason Morris discusses the notion of “rules as code”⁴³. Rules as code is a methodology for creating and applying legal rules, accounting rules, reporting rules, auditing rules and such in the digital age. Some of the important features of Rules as Code are⁴⁴:

- Legislation, statutes, and regulations should be drafted in a natural language and in the form of machine-readable rules at the same time.
- Rules should be declarative.
- The platform on which the legislation is encoded should be open, accountable, transparent and standardized.
- Definitions should be consistent across all acts, statutes, and regulations; not only within them. Each law should add to the shared dictionary of terms.

Network Affect

The network effects⁴⁵ (Metcalfe’s Law⁴⁶) have become an essential component of a successful digital businesses. Network effects typically account for 70% of the value of digitally-related companies. Metcalfe's Law states that a network's impact is the square of the number of nodes in the network.

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

For more information about the network affect, I would recommend *New Rules for the New Economy*⁴⁷. The thesis of *New Rules for the New Economy* is that we are now living in an economy based on ideas and communication rather than energy and atoms. Further, this "new" economy has distinct laws or rules so it behaves differently than the previous industrial economy. To do well in the new regime, we need to grasp the new dynamics of information.

⁴³ YouTube.com, Jason Morris, *How programming can make the law more accessible*, <https://youtu.be/d5Mt-Q9K7tU>

⁴⁴ American Bar Association, Jason Morris, *Rules as Code*, <https://www.lawpracticetoday.org/article/rules-code/>

⁴⁵ Wikipedia, *Network Effect*, https://en.wikipedia.org/wiki/Network_effect

⁴⁶ Metcalfe’s Law, <https://www.thegeniusworks.com/2020/02/metcalfes-law-explains-how-the-value-of-networks-grow-exponentially-there-are-5-types-of-network-effects/>

⁴⁷ Kevin Kelly, *New Rules for the New Economy*, <http://xbrl.squarespace.com/journal/2021/4/5/new-rules-for-the-new-economy.html>

Gamified Incentive Model

Per Wikipedia, gamification⁴⁸ is the strategic attempt to enhance systems, services, organizations and activities in order to create similar experiences to those experienced when playing games in order to motivate and engage users of a system.

Gamification was introduced by John von Neumann and Oskar Morgenstern's *Theory of Games and Economic Theory*⁴⁹. Now it is commonly referred to game theory or gamification.

A game⁵⁰ is defined as any interaction between multiple parties in which each party's payoff is affected by the decisions of others.

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

Logic

Logic is a set of principles that forms a **framework for correct reasoning**. Logic is a process of deducing information correctly. Logic is about the correct methods that can be used to prove a statement is true or false. Logic tells us exactly what is meant. Logic allows systems to be proven.

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

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

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

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

⁴⁸ Wikipedia, Gamification, <https://en.wikipedia.org/wiki/Gamification>

⁴⁹ Neumann and Oskar Morgenstern, *Theory of Games and Economic Theory*, <https://books.google.com/books?id=jCN5aNJ-n-OC&printsec=frontcover#v=onepage&q&f=false>

⁵⁰ YouTube.com, *Game Theory: The Science of Decision-Making*, <https://youtu.be/MHS-htjGgSY>

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

Metalogic

Enter the notion of metalogic⁵¹. **Metalogic** relates to the comparison between the logic of different systems. As pointed on in *Specifying the Rule Metalogic on the Web*⁵², interoperability issues can become problematic if you are using different logics to perform work and evaluate two different logical systems such as two different financial report models. Both systems, although different software applications, should derive the same logical conclusions.

Now, I have mentioned that there are a number of different logic systems that could be used to represent a logical system: OWL+SHACL+RDF, Modern Prolog, ISO Prolog, Datalog, PSOA, GQL/Cypher, XBRL+More, SQL+More⁵³. We will discuss these different implementation alternatives in a moment.

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

Interoperability

There have been many different ways to explain what interoperability is and how to achieve it; it seems that there is convergence emerging on this four-level interoperability model^{54,55}:

- **Foundational** (Level 1): Establishes the *inter-connectivity requirements* needed for one system or application to securely communicate data to and receive data from another.
- **Structural** (Level 2): Defines the *format, syntax and organization of data exchange* including at the data field level for interpretation.
- **Semantic** (Level 3): Provides for *common underlying models and codification of the data* including the use of data elements with standardized definitions from publicly available value sets and coding vocabularies, providing shared understanding and meaning to the user.

⁵¹ Ted Sider, Logic of Philosophy, page 6, http://tedsider.org/books/lfp_sample.pdf#page=6

⁵² Harold Boley, *Specifying the Rule Metalogic on the Web*, <http://ruleml.org/ruleml.org/metalogic/RuleMetaLogic2011-10-29.pdf>

⁵³ Answering the Question of Which Logic, <http://xbrl.squarespace.com/journal/2020/8/15/answering-the-question-of-which-logic.html>

⁵⁴ HIMSS, Interoperability in Healthcare, <https://www.himss.org/resources/interoperability-healthcare>

⁵⁵ Shawn Riley, *What is Interoperability*, https://www.linkedin.com/posts/shawnriley71_what-is-interoperability-it-is-the-ability-activity-6703288197729918976-FFYD/

- **Organizational** (Level 4): Includes *governance, policy, social, legal and organizational considerations* to facilitate the secure, seamless and timely communication and use of data both *within and between* organizations, entities and individuals. These components enable shared consent, trust and integrated end-user processes and workflows.

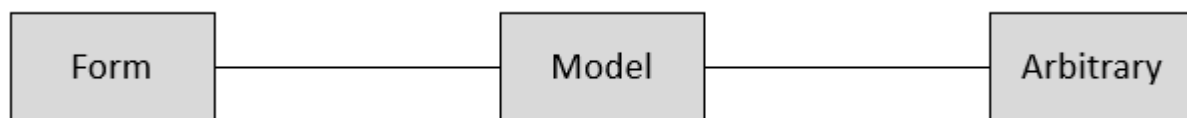
Standards help provide interoperability. For example,

- XBRL International⁵⁶ provides the XBRL technical syntax⁵⁷ global standard (including a conformance suite for testing software) to enable syntax interoperability
- Object Management Group⁵⁸ (OMG) provides the Standard Business Report Model⁵⁹ (SBRM) to provide a logical conceptualization of a business report
- RuleML⁶⁰ helps to provide business rule and logic interoperability
- Logical Theory Describing Financial Report⁶¹ provides semantics of a financial report, building on the SBRM model of a business report

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

Model

Models provide flexibility and controllability. Think of it this way. Intuit's TurboTax was provided as a rudimentary example of computational law. TurboTax works with tax forms. Tax forms are static, they don't change for a tax year. Because forms don't change, it is trivial to get a computer to control a form. At the other end of the spectrum is arbitrary. Computers cannot really work with arbitrary; things are too unpredictable. In between, where you get the control offered by a form but the necessary flexibility is by creating a model. Think of a model as multiple different possible forms.



For example, financial reports are not forms. Each company's report can have different line items and line items can be organized under different subtotals. But what line items can be used and what

⁵⁶ XBRL International, XBRL, <http://xbrl.org>

⁵⁷ XBRL International, Standards, <https://specifications.xbrl.org/specifications.html>

⁵⁸ OMG, <https://www.omg.org>

⁵⁹ OMG, Standard Business Report Model (SBRM), <https://www.omg.org/intro/SBRM.pdf>

⁶⁰ RuleML, http://wiki.ruleml.org/index.php/RuleML_Home

⁶¹ Logical Theory Describing Financial Report, <http://xbrl.squarespace.com/logical-theory-financial-rep/>

different organizations can be used follow patterns. Each of those permissible patterns constitutes a model⁶².

Metamodel

Metamodels provide a specification for a model. For example, the Securities and Exchange Commission (SEC) provides a metamodel for an XBRL-based digital financial report. Essentially, the Edgar Filer Manual provides that metamodel. When a company creates their financial report model, they have to conform to that SEC metamodel.

The European Single Market Authority (ESMA) uses a slightly different metamodel than the SEC. Companies reporting to the ESMA use the model defined by the European Single Electronic Format (ESEF).

Both the SEC and ESEF follow the meta-metamodel defined by the OMG Standard Business Report Model (SBRM)⁶³. SBRM provides a logical conceptualization of a business report.

Complexity

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

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

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

⁶² *Understanding Digital*, Intermediate Components, page 38,
<http://xbrrsite.azurewebsites.net/2020/Library/UnderstandingDigital.pdf#page=38>

⁶³ OMG, Standard Business Report Model (SBRM), <https://www.omg.org/intro/SBRM.pdf>

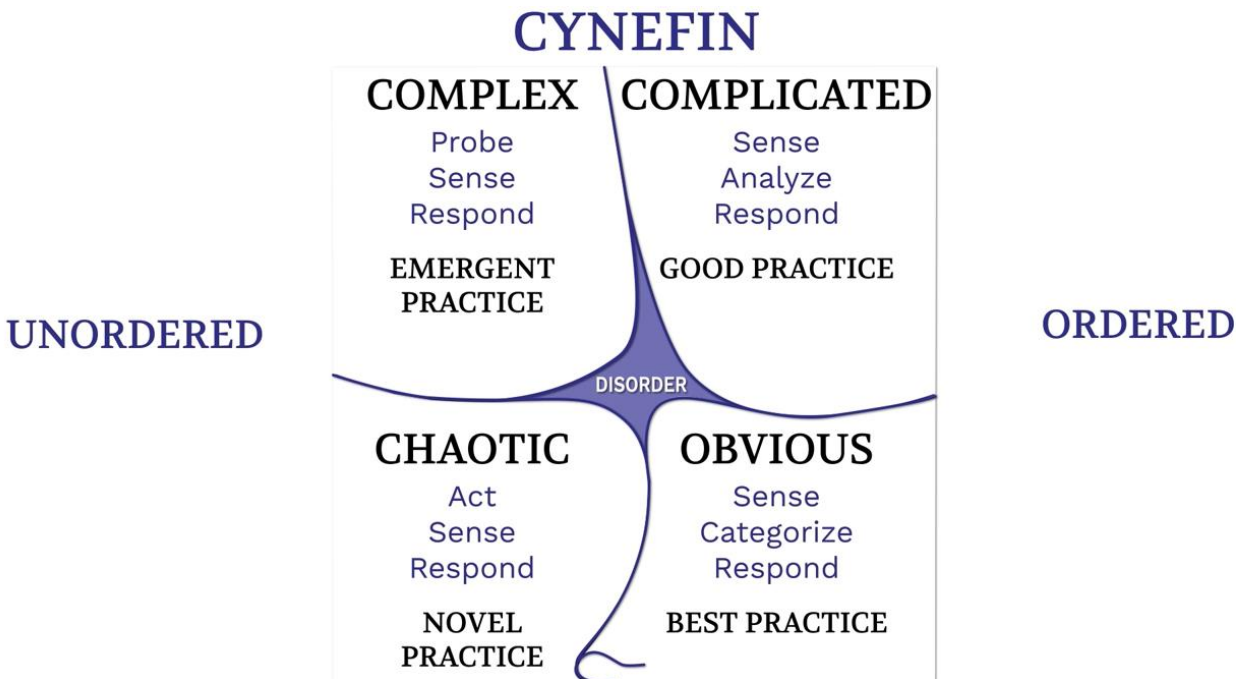
But say you remove one of the parts of the mousetrap. The mousetrap will no longer function as it was designed; it will not work. That is **irreducible complexity**: the complexity of the design requires that it can't be reduced any farther without losing functionality.

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

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

The Cynefin Framework⁶⁴ is a conceptual framework for decision making and thinking about complexity. The framework was created in 1999 by David Snowden of IBM Global Services to help IBM to manage intellectual capital.

For more information about the Cynefin framework, I would recommend the video *Complexity, Cynefin, and Agile*⁶⁵. The Cynefin framework helps you understand the difference between ordered systems and unordered systems; best practices, good practices, and novel practices; simple, complicated, and complex systems; and other such dynamics.



⁶⁴ Wikipedia, *Cynefin Framework*, https://en.wikipedia.org/wiki/Cynefin_framework

⁶⁵ YouTube.com, *Complexity, Cynefin, and Agile*, <https://youtu.be/-F4enP8oBFM>

Viable Implementation Alternatives

Figuring out which logic to use is a "dance" between expressivity⁶⁶ and tractability⁶⁷, trying to get the right equilibrium for the task being performed. The logic needs to be as powerful as possible but also as reliable as possible (i.e. controllable).

My confidence is pretty high that all of the following alternatives seem to provide enough logic, but most also have specific known control issues associated with them so craftsmen need to make adjustments to make sure things work as would be expected:

- **Ontology + Rules:** For example, OWL⁶⁸ (or SWRL) + SHACL⁶⁹ + RDF⁷⁰ (or N3) provide sufficient fragments of first order logic. (Some call this Modern Symbolic AI⁷¹)
- **Modern Prolog:** Prolog such as SWI Prolog⁷² or Scryer Prolog⁷³ seem to have all of the necessary functionality. The up side is that there are a lot of Prolog implementations⁷⁴. The down side is that none of these Prologs can call itself "the standard". Each has pros and cons. Prolog interoperates with relational (SQL) databases.
- **ISO Prolog:** ISO has created a standard Prolog⁷⁵. ISO Prolog can be regarded as a subset of Full Prolog. There is solid motivation for implementations to support ISO Prolog as the international standard Prolog, many already do to one degree or another.
- **Datalog:** Datalog⁷⁶, or "function-free Horn Logic", is more tractable than Horn Logic⁷⁷ (Pure Prolog) and ISP Prolog (Full Prolog). RuleML.org points out⁷⁸, "Datalog is the language in the intersection of SQL and Prolog. It can thus be considered as the subset of logic programming needed for representing the information of relational databases, including (recursive) views." So Datalog interoperates with relational databases.
- **PSOA RuleML:** PSOA⁷⁹ (Positional-Slotted Object-Applicative) RuleML is a multi-paradigm, particularly graph-relational, data and rule language. PSOA interoperates with

⁶⁶ Revisiting the Knowledge Representation Spectrum, <http://xbrl.squarespace.com/journal/2019/10/9/revisiting-the-knowledge-representation-spectrum.html>

⁶⁷ Dictionary.com, *Tractability*, <https://www.dictionary.com/browse/tractability>

⁶⁸ W3C, *OWL*, <https://www.w3.org/TR/owl2-overview/>

⁶⁹ W3C, *SHACL*, <https://www.w3.org/TR/shacl/>

⁷⁰ W3C, *RDF*, <https://www.w3.org/RDF/>

⁷¹ Shawn Riley, *Modern Symbolic AI in 2020*, <https://medium.com/@shawn.p.riley/modern-symbolic-ai-in-2020-dfcc27abbc5c>

⁷² SWI Prolog, <https://www.swi-prolog.org/>

⁷³ Scryer Prolog, <https://github.com/mthom/scryer-prolog>

⁷⁴ Wikipedia, *Comparison of Prolog Implementations*, https://en.wikipedia.org/wiki/Comparison_of_Prolog_implementations

⁷⁵ ISO, *ISO Prolog*, <https://www.iso.org/standard/21413.html>

⁷⁶ Wikipedia, *Datalog*, <https://en.wikipedia.org/wiki/Datalog>

⁷⁷ Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause

⁷⁸ RuleML.org, <http://ruleml.org/papers/Primer/RuleMLPrimer2012-08-09/RuleMLPrimer-p3-2012-08-09.html>

⁷⁹ RuleML.org, *PSOA*, http://wiki.ruleml.org/index.php/PSOA_RuleML

graph and relational databases. RuleML.org points out⁸⁰, “PSOA RuleML’s databases (fact bases) generalize the instance level of Graph and Relational Databases; its knowledge bases complement facts by rules for deductive retrieval (extending the Datalog-level, function-free expressiveness of Deductive Databases to the Horn-logic expressiveness of Logic Programming), interoperation, and reasoning, as well as for optionally emulating part of the schema level.”

- **GQL/Cypher:** GQL⁸¹ is an ISO project⁸² to create a global standard query language (like SQL) for graph databases, graph query language. Open Cypher⁸³ which is based on Cypher is the query language of Neo4j.
- **SQL + More:** While it is proven⁸⁴ that you can store XBRL-based information in a relational database; you have to add functionality to process the information. Essentially, you have to construct a rules engine to process the information and prove the system is properly functioning. This is very possible but tends to not be very efficient.
- **XBRL + SBRM + More:** XBRL⁸⁵ is an open standard technical syntax published by XBRL International, SBRM⁸⁶ is a forthcoming standard to be published by OMG that formalizes a logical conceptualization of a business report. While XBRL provides the functionality to represent all that is needed to express knowledge and much of what is necessary to process that knowledge and prove the knowledge is represented correctly. However, certain specific processing is missing that must be supplemented to create a complete system. As such, that additional processing logic must be provided.

There are undoubtedly other logic engines that can be used to process XBRL-based digital financial reports. Other completely different approaches such as the decision model approach⁸⁷ could possibly be used but would need to include an ontology-type component. Any syntax used should be 100% convertible to all other syntaxes and be able to round tripped back into the original syntax. Then, you could switch between whatever approach you wanted.

These approaches can be grouped into three problem solving logic paradigms⁸⁸:

⁸⁰ RuleML.org, *PSOA RuleML Bridges Graph and Relational Databases*, https://wiki.ruleml.org/index.php/PSOA_RuleML_Bridges_Graph_and_Relational_Databases

⁸¹ GQL Standards.org, *GQL Standard*, <https://www.gqlstandards.org/>

⁸² Wikipedia, *GQL Graph Query Language*, https://en.wikipedia.org/wiki/GQL_Graph_Query_Language

⁸³ OpenCypher.org, *Open Cypher*, <https://www.opencypher.org/>

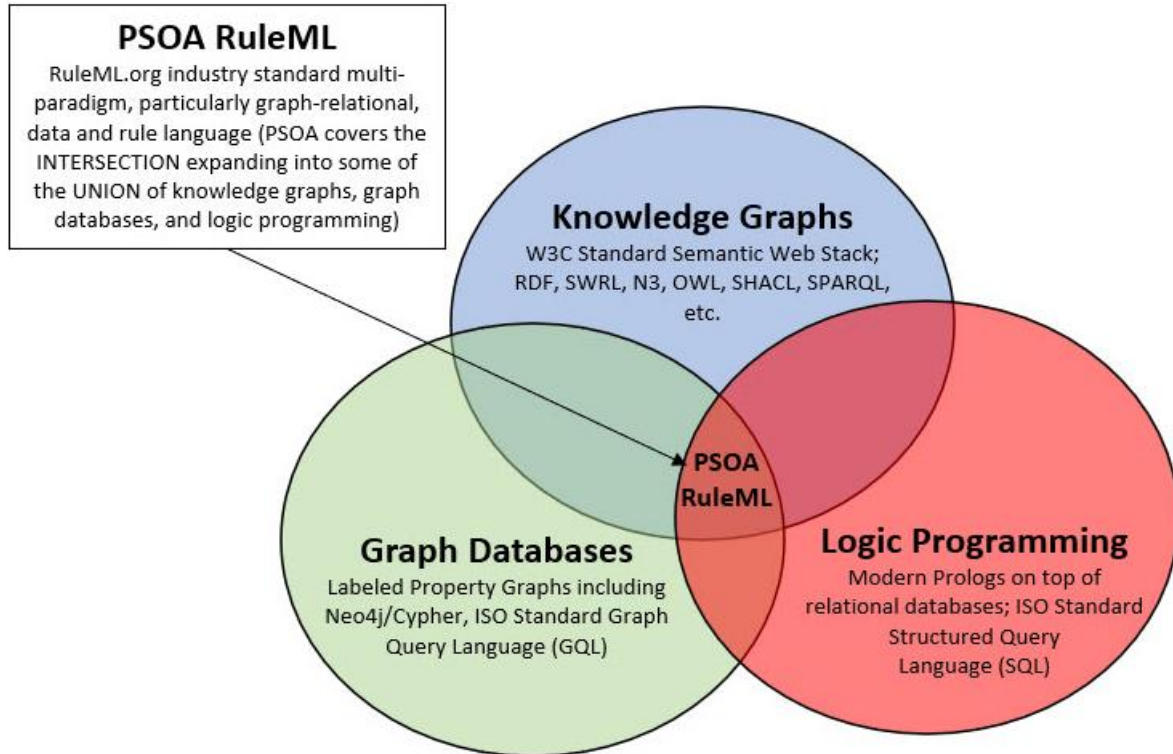
⁸⁴ Proof representation, <http://xbrl.azurewebsites.net/2020/master/proof/index.html>

⁸⁵ XBRL International, <https://www.xbrl.org/>

⁸⁶ OMG, SBRM, <https://www.omg.org/intro/SBRM.pdf>

⁸⁷ Wikipedia, *Decision Model*, https://en.wikipedia.org/wiki/Decision_model

⁸⁸ Problem Solving Logic Paradigms, <http://xbrl.squarespace.com/journal/2020/9/15/primary-problem-solving-logic-paradigms.html>



Converting between these logics is very possible. For example, converting between RDF and labeled property graphs is possible⁸⁹. Converting from RDF to SWI Prolog is possible⁹⁰. But 100% conversion is limited to the least common denominator, the set of logic that each alternative possesses.

Universal vs Domain Specific Applications

Having high-level metamodels such as the forthcoming Standard Business Report Model⁹¹ (SBRM) and Logical Theory Describing Financial Report⁹² (see). Plus, creating the base metadata, such as the US GAAP Financial Reporting Metadata⁹³ leveraging that high-level metamodel makes all of this extremely technical stuff far less technical to business professionals. How? A few trained professionals create the high-level metadata but every

⁸⁹ Neo4j, Jesús Barrasa, *RDF Triple Stores vs. Labeled Property Graphs: What's the Difference?*, <https://neo4j.com/blog/rdf-triple-store-vs-labeled-property-graph-difference/>

⁹⁰ Samuel Lampa, *SWI-Prolog as a Semantic Web Tool for semantic querying in Bioclipse: Integration and performance benchmarking*, <https://www.diva-portal.org/smash/get/diva2:398839/FULLTEXT01.pdf>

⁹¹ *SBRM Progress Report*, <http://xbrl.squarespace.com/journal/2020/1/30/sbrm-progress-report.html>

⁹² *Logical Theory Describing Financial Report*, <http://xbrl.squarespace.com/logical-theory-financial-rep/>

⁹³ *US GAAP Financial Reporting Scheme*, <http://xbrl.azurewebsites.net/2020/reporting-scheme/us-gaap/documentation/Home.html>

software application and business domain professional benefits from that metadata and high-level models. Further, software creation costs are reduced. How is that possible? Read on.

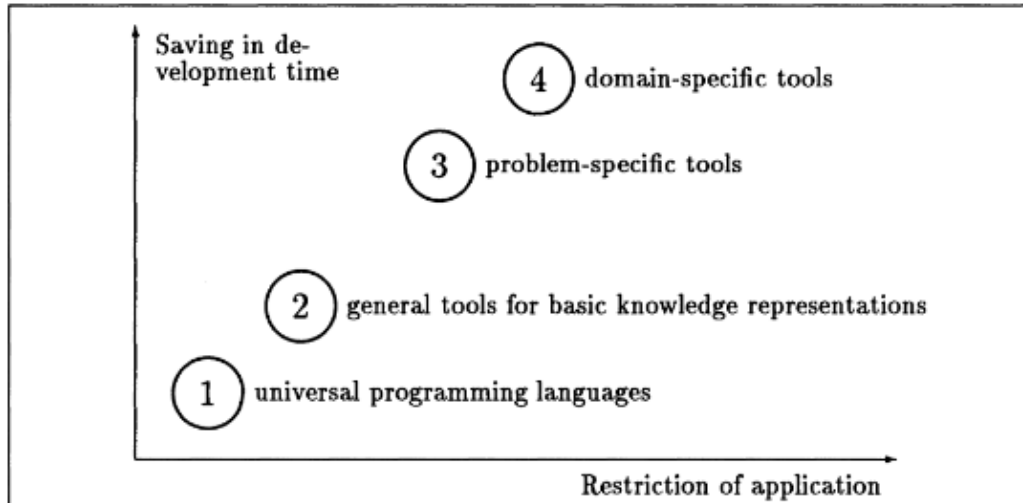
In his book *Systematic Introduction to Expert Systems*⁹⁴, Frank Puppe provides the graphic below. The graphic basically points out that **universal, general tools** are less restrictive but cost more to create than **domain-specific tools**. In addition to universal, general tools being more costly to create and more difficult to create; domain specific tools are easier to create and much, much easier for business professionals to use because of the restrictions.

So, a “restriction” is not a flaw. **The restriction is what makes the tool easier to use and cost less and make easier to develop**. You don’t need the universe of all possible options for a specific domain; you only need to create what that specific domain needs. As **long as you get these restrictions correct**, they really are not “restrictions” of the domain, they are the “boundaries” of the domain. You don’t need them.

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

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

⁹⁴ Frank Puppe, *Systematic Introduction to Expert Systems*, page 11, https://books.google.com/books?id=kKqCAAQBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false



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

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

Process Control

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

Control + Rules = Effective Automation (High Quality)

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

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

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

Lean Six Sigma

Lean Six Sigma⁹⁵ is a discipline that combines the problem-solving methodologies and quality enhancement techniques of Six Sigma⁹⁶ with the process improvement tools and efficiency concepts of Lean Manufacturing⁹⁷. Born in the manufacturing sector, Lean Six Sigma works to produce products and services in a way that meets consumer demand without creating wasted time, money and resources.

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

Quality and the lack of quality both have a cost. The 1-10-100 Rule is related to what’s called “the cost of quality.” Essentially, the rule states that prevention is less costly than correction is less costly than failure. It makes more sense to invest \$1 in prevention, than to spend \$10 on correction. That in turn makes more sense than to incur the cost of a \$100 failure⁹⁸.

To learn more about Lean Six Sigma techniques, principles, tools, and philosophies I would recommend the chapter *Lean Six Sigma*⁹⁹ of *Mastering XBRL-based Digital Financial Reporting*.

⁹⁵ Wikipedia, *Lean Six Sigma*, https://en.wikipedia.org/wiki/Lean_Six_Sigma

⁹⁶ Wikipedia, *Six Sigma*, https://en.wikipedia.org/wiki/Six_Sigma

⁹⁷ Wikipedia, *Lean Manufacturing*, https://en.wikipedia.org/wiki/Lean_manufacturing

⁹⁸ Michael Canic, *The Cost of Quality: The 1-10-100 Rule*, <https://www.makingstrategyhappen.com/the-cost-of-quality-the-1-10-100-rule/>

⁹⁹ Charles Hoffman, CPA, asdf, http://www.xbrlsite.com/mastering/Part01_Chapter02.K_LeanSixSigma.pdf

Building on the Shoulders of Giants

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

A logical system¹⁰⁰ is a type of formal system¹⁰¹. A financial report is a type of formal system. To be crystal clear what I am trying to create is a **finite model-based deductive first-order logic system**¹⁰².

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

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

- **Systems theory:** A system¹⁰³ is a cohesive conglomeration of interrelated and interdependent parts that is either natural or man-made. Systems theory explains logical systems.
- **Logical theory:** (a.k.a. logical system) There are many approaches to representing “ontology-like things” in machine-readable form¹⁰⁴, a logical theory being the most powerful.
- **Proof theory:** The ideas of proof theory¹⁰⁵ can be used to verify the correctness of logical systems and computer programs working with those machine-readable logical systems.
- **Set theory:** Set theory is foundational to logic and mathematics. Axiomatic (Zermelo–Fraenkel) set theory¹⁰⁶ is preferred to naïve set theory.

¹⁰⁰ Wikipedia, *Logical Systems*, https://en.wikipedia.org/wiki/Logic#Logical_systems

¹⁰¹ Wikipedia, *Formal System*, https://en.wikipedia.org/wiki/Formal_system

¹⁰² Wikipedia, *First-order Logic, Deductive System*, https://en.wikipedia.org/wiki/First-order_logic#Deductive_systems

¹⁰³ Wikipedia, *Systems Theory*, https://en.wikipedia.org/wiki/Systems_theory

¹⁰⁴ Difference between Taxonomy, Conceptual Model, Logical Theory, <http://xbrl.squarespace.com/journal/2018/12/11/difference-between-taxonomy-conceptual-model-logical-theory.html>

¹⁰⁵ Stanford University, *The Development of Proof Theory, The Aims of Proof Theory*, <https://plato.stanford.edu/entries/proof-theory-development/#AimProThe>

¹⁰⁶ Wikipedia, *Set Theory, Axiomatic Set Theory*, https://en.wikipedia.org/wiki/Set_theory#Axiomatic_set_theory

- **Graph theory:** Directed acyclic graphs¹⁰⁷ are preferred to less powerful “trees” and graphs which contain cycles that can lead to catastrophic problems caused by those cycles.
- **Logic:** Logic is a formal communications tool. **Horn logic**¹⁰⁸ is a subset of first-order logic which is immune from logical paradoxes should be used as contrast to more powerful but also more problematic first order logic features. Note that deductive reasoning is leveraged for the process of creating a financial report and not inductive reasoning (i.e. machine learning)
- **Model theory:** Model theory is a way to think about flexibility. Safer finite model theory¹⁰⁹ is preferable to general model theory.
- **World view:** The following are common issues which appear when implementing logical systems in machine-readable form, the safest and most reliable alternatives are:
 - closed world assumption¹¹⁰ which is used by relational databases is preferred to the open world assumption which can have decidability issues¹¹¹;
 - negation as failure¹¹² should be explicitly stated;
 - unique name assumption¹¹³ should be explicitly stated;

Business professionals are (a) not capable of having precise discussions of these sorts of issues with software engineers, (b) don't care to have such technical discussions about these sorts of issues with software engineers, (c) are not interested in the theoretical or philosophical or religious debates that commonly exist related to these alternatives, (d) if the alternatives were appropriately articulated to a business professional, who tend to be very practical, they would **most often error on the side of safety and reliability.**

While some implementations can have decidability issues or termination problems or other such issues, a master craftsman is knowledgeable of these issues and so they can work around such problems.

¹⁰⁷ Wikipedia, *Directed Acyclic Graph*, https://en.wikipedia.org/wiki/Directed_acyclic_graph

¹⁰⁸ Wikipedia, *Horn Logic*, https://en.wikipedia.org/wiki/Horn_clause

¹⁰⁹ Wikipedia, *Finite Model Theory*, https://en.wikipedia.org/wiki/Finite_model_theory

¹¹⁰ Wikipedia, *Closed World Assumption*, https://en.wikipedia.org/wiki/Closed-world_assumption

¹¹¹ Wikipedia, *Undecidability Problem*, https://en.wikipedia.org/wiki/Undecidable_problem

¹¹² Wikipedia, *Negation as Failure*, https://en.wikipedia.org/wiki/Negation_as_failure

¹¹³ Wikipedia, *Unique Name Assumption*, https://en.wikipedia.org/wiki/Unique_name_assumption

Effective Computational Professional Services

Clearly for computational professional services to be useful, it actually needs to work, be reliable, be predictable, and provide benefits in terms of better, faster, or cheaper professional services offerings.

‘Hope’ is not a sound engineering principle. To make computational professional services work one needs “know how”. Know how is a type of practical knowledge. A **best practice** is a method or technique that has been generally accepted as superior to any other known alternatives because it produces results that are superior to those achieved by other means or because it has become a standard way of doing things.

Rather than rushing into the details; take a step back consider the utility that a framework, theory, principles, and method would very likely provide. Then, brick-by-brick, much like building a house, business domain experts and software engineers can create tools that automate certain types of tasks in that process and let computational professional services unfold.

Computational professional services is not about computers replacing humans. Computational professional services is about using machines to do what they do best and humans to do what they do best. Computational professional services is about human-machine collaboration; much like how a calculator is used to help humans do math. Computational professional services is about augmenting the capabilities of humans by leveraging machines.

Framework, Theory, Principles, Method

What is conspicuously lacking from most people’s minds is a broad framework let alone a theory and principles on how to think about computational professional services.

A **framework** is an aid that enables a community of stakeholders with a set of rules, ideas, or beliefs which provides a structure in order to think about or implement something. A **theory** enables a community of stakeholders trying to achieve a specific goal or objective or a range of goals/objectives to agree on important statements used for capturing meaning or representing a shared understanding of and knowledge in some universe of discourse. **Principles** help you think about something thoroughly and consistently. Overcoming disagreements between stakeholders and even within groups of stakeholders is important and principles can help in that communications process. A good practices/best practices based method¹¹⁴ for creating a process control mechanism that consistently yields high-quality XBRL-based financial reports where the model can be “reshaped” or “altered” by report creators has been created and tested and consistently yields high-quality XBRL-based financial reports.

¹¹⁴ Charles Hoffman, CPA, *Method – Terse Explanation*, <http://xbrlsite.azurewebsites.net/2020/library/MethodTerse.pdf>

The *Logical Theory Describing Financial Report*¹¹⁵ provides a framework, theory, and principles for thinking about XBRL-based digital financial reporting. This can serve as an example of how to think about computational professional services.

Merkle DAG, Merkle Tree, Merkle Proof

Knowledge graphs¹¹⁶, DAGs (a.k.a. directed acyclic graphs¹¹⁷), Merkle Trees¹¹⁸, and Merkle Proofs¹¹⁹ will transform (are transforming) accounting, reporting, auditing, and analysis profoundly and forever.

As I have pointed out previously¹²⁰, an XBRL-based financial report is a knowledge graph. Not only are such reports knowledge graphs, they are special types of knowledge graphs that don't have "loops" or cycles. Those special types of knowledge graphs are called directed acyclic graphs.

A Merkle DAG¹²¹ is a type of Merkle Tree. You can create a Merkle DAG from the information contained within an XBRL-based digital financial report. When thinking about this, most software engineers think about a hash of the XBRL technical syntax that makes up the report. But you can also think of this while considering the logic of the digital financial report. That logic is represented by all of the rules related to the report that has been represented using the XBRL technical syntax.

A Merkle proof¹²² is an approach to verifying that information stored, transferred, handled, processed, or otherwise used by a computer has not been changed or otherwise tampered with. You can also verify that the rules used to verify the logic of the report have not been changed.

The InterPlanetary File System (IPFS)¹²³ is a peer-to-peer distributed file system that seeks to connect all computing devices with the same system of files. Today, the internet uses location-based addressing. IPFS uses content-based addressing. So, for example, an auditor can verify that an XBRL-based financial report is considered complete, consistent, and properly functioning and the set of rules used to make that determination can be both defined and specified; included in the Merkle DAG and proven using the Merkle proof. This provides unprecedented transparency and potentially trust.

¹¹⁵ Charles Hoffman, CPA, *Logical Theory Describing Financial Report*, <http://xbrl.squarespace.com/logical-theory-financial-rep/>

¹¹⁶ Knowledge Graphs, <http://xbrl.squarespace.com/journal/2021/6/27/the-knowledge-graph-cookbook-recipes-that-work.html>

¹¹⁷ YouTube.com, *Quick Tip - What's a DAG, and Why Should I Care?*, <https://youtu.be/lltIGJOHYgo>

¹¹⁸ Changlly, *Merkle Trees Explained*, <https://changelly.com/blog/merkle-tree-explain/>

¹¹⁹ Medium, *Merkle Proof Explained*, <https://medium.com/crypto-0-nite/merkle-proofs-explained-6dd429623dc5>

¹²⁰ Understanding Financial Reports are Knowledge Graphs, <http://xbrl.squarespace.com/journal/2021/6/18/understanding-financial-report-knowledge-graph.html>

¹²¹ IPFS, *Merkle DAG*, <https://docs.ipfs.io/concepts/merkle-dag/>

¹²² Medium, *Merkle Proof Explained*, <https://medium.com/crypto-0-nite/merkle-proofs-explained-6dd429623dc5>

¹²³ IPFS, <http://xbrl.squarespace.com/journal/2021/8/15/ipfs.html>

My method¹²⁴ specifies a minimum set of information that must be used to verify an XBRL-based financial report. Effectively, that method defines a level 5 financial report¹²⁵.

If you use Merkle trees and Merkle proofs to verify *the report* and put those hashes on a publicly available digital distributed ledger then you can make known specifically what was reported, understand what information was used to verify that reported information, and be sure that the information has not been tampered with. This, I guess, is how you would create a level 6 digital financial report.

If you use a Merkle tree and Merkle proof at the transaction level you could not only verify the report but also verify the set of transactions which were used to generate that report. This, I guess, is how you would create a level 7 digital financial report.

Wow! This is all based on mathematics. Here's is a prototype XBRL-based financial report¹²⁶ plus 94% of the rules that I have come up with to make that report consistent with my method. Here is another prototype that includes the transactions¹²⁷ and, I believe, has 100% of the core rules necessary.

Immutable Digital Distributed Ledgers

A digital distributed ledger is an indestructible and un-editable decentralized computer record, or ledger. A digital distributed ledger provides a full and complete history of transactions in that ledger. Ledgers can be as public and open or private and limited as the use case demands. Ledgers can be permissioned or permission less in determining who can add new transactions. Different approaches can be used to determine how new transactions are authorized (proof-of-stake, proof-of-work, consensus, identity mechanisms) before they can add new information to the ledger. Ledgers can be interlinked with one or more other ledgers.

To find out more about digital distributed ledgers please read the chapter *Digital Distributed Ledgers*¹²⁸ in *Mastering XBRL-based Digital Financial Reporting*¹²⁹.

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.

¹²⁴ Method – Terse Explanation, <http://xbrlsite.azurewebsites.net/2020/library/MethodTerse.pdf>

¹²⁵ Financial Report Levels, <http://xbrl.squarespace.com/journal/2021/4/5/financial-report-levels.html>

¹²⁶ Knowledge Graph of Microsoft 10-K Financial Report, <http://xbrl.squarespace.com/journal/2021/7/12/knowledge-graph-of-microsoft-10-k-financial-report.html>

¹²⁷ Effective Automation of Record to Report (Iteration #4), <http://xbrl.squarespace.com/journal/2021/1/25/effective-automation-of-record-to-report-process-iteration-4.html>

¹²⁸ Digital Distributed Ledgers, http://www.xbrlsite.com/mastering/Part01_Chapter02.J_DistributedLedgers.pdf

¹²⁹ Mastering XBRL-based Digital Financial Reporting, <http://xbrl.squarespace.com/mastering-xbrl/>

Best practices (or good practices) are techniques that have produced outstanding results in other situations, inside or outside of a particular organization and which can be validated, codified, and shared with others and recommended as models to follow¹³⁰.

Conclusion

While XBRL-based digital financial reporting does not have all the answers and is not perfect, it does provide a tremendous amount of useful insight. To understand more details, please read the 161 pages that make up the *XBRL-based Digital Financial Reporting Jump Start*¹³¹. Want even more details? Try *Mastering XBRL-based Digital Financial Reporting*¹³².

¹³⁰ European Guide to good Practice in Knowledge Management - Part 5: KM Terminology, page 3 (PDF page 9), <http://arielsheen.com/wp-content/uploads/2019/10/CEN-CWA14924-05-2004-Mar.pdf#page=9>

¹³¹ XBRL-based Digital Financial Reporting Jump Start, <http://xbrl.squarespace.com/journal/2020/8/6/xbrl-based-digital-financial-reporting-jump-start.html>

¹³² Charles Hoffman, CPA, Mastering XBRL-based Digital Financial Reporting, <http://xbrl.squarespace.com/mastering-xbrl/>