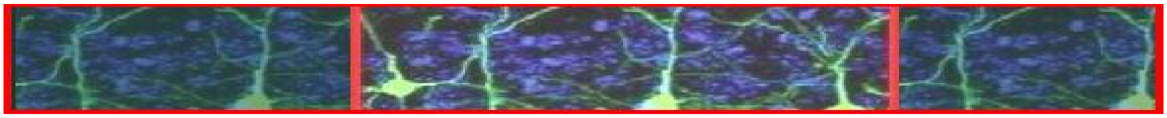


Knowledge Engineering Using the Expertool Paradigm: Modeling Operations as Complex Systems

Joe Glick, President

OVERVIEW

The intense dynamics of emerging regulation, global competition and escalating systemic dependencies are creating daunting challenges to the management and adaptation of operations and systems. The key challenges include:

- bridging the rapidly scaling gap between data stores and knowledge utility
- dynamic integration of information silos, and organizational layers of strategy, tactics, operations and engineering
- holistic analysis of systemic risks, impacts and response alternatives

Meeting these challenges requires the ability to holistically model the organization in its environment as a complex system and to capture computable human knowledge and expertise.

The Expertool Paradigm is a knowledge engineering platform that combines an abstract, neural, universal knowledge modeling toolset with a methodology that leverages successful biomimetic robotics design patterns and related advances in cognitive science. The Expertool platform is optimized for modeling human cognition and granular interactions in complex systems.

We evolved the software and methodology over 15 years in a real world "lab" – as we designed and delivered complex solutions to government, academia and enterprise clients, including some of the world's largest financial institutions. Today, due to the unique capability for computable context representation and modeling human expertise, our platform is enabling the Knowledge Engineering for Nanoinformatics initiative[1] sponsored by the National Science Foundation, which includes projects for biomedical ontology and materials genome mapping.

Leveraging the capabilities of the Expertool platform does not require architectural changes or infrastructure investments. The resulting models can be utilized as:

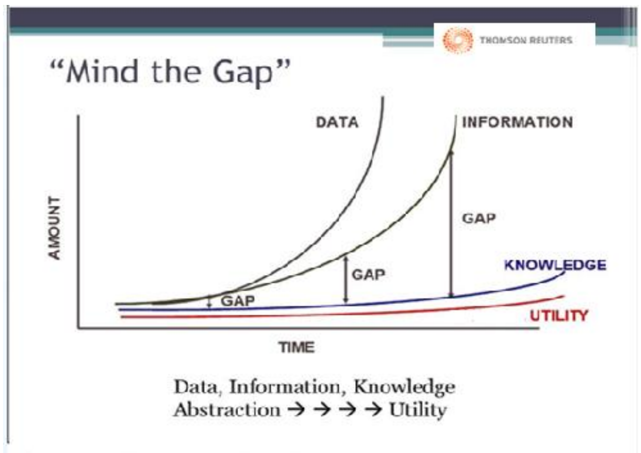
- standalone or integrated analytical environments
- desktop expert applications
- backend engines providing complex services to diverse applications

The complexity, dynamic evolution and systemic management requirements of the Dodd-Frank legislation make the Expertool platform an invaluable toolset for solution architecture and implementation.

[1] www.nanoinformatics.org

THE KNOWLEDGE AND EXPERTISE GAP

While the importance of holistic, systemic modeling is well understood, and it is in fact mandated for risk management by Dodd-Frank, modeling dynamic and complex systems of significant scale is beyond the reach of traditional enterprise technology. The reality and significance of this capability shortfall is seen in the growing gap between information and utility, identified clearly in the Thompson Reuters slide below (2011).



As the slide concludes, abstraction is required to transform data into information, and then into knowledge, and then into utility. However, the operational or competitive value of the delivered utility is dependent on level of expertise that is used to make abstraction decisions. Expertise includes knowledge of a domain and the “know-how” to apply the knowledge dynamically to diverse problem scenarios[2].

Expertise capture is also critical because in addition to abstraction decisions, relevance decisions are required to deal with the scaling potential interactions. For example, one might not think that optimizing a route to deliver 25 packages is highly complex, but the number of factors that UPS considers results in what they call a “combinational explosion…for 25 stops there are more than thirteen trillion, trillion delivery paths…it would take 122 million years to compute every different path.”[3]

Since exhaustive modeling of potential interactions is not feasible, human expertise is required to perform relevance analyses, usually via extensive mapping exercises using spreadsheets. This approach is slow, error-prone and very difficult to translate into a set of unambiguous engineering requirements.

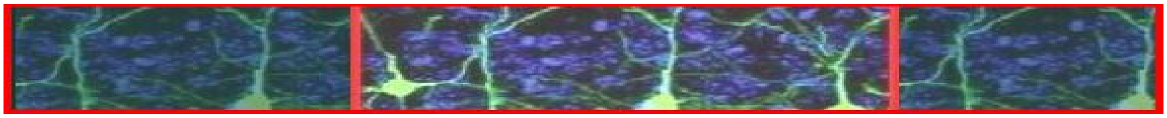
The Expertool neural platform and cognitive methodology provide an alternative that is significantly more effective, efficient and scalable[4].

---

[2] Morabito, J., Sack, I,. Bhate, A., 1999 *Organization Modeling*, Prentice Hall PTR

[3] UPS (2008) *Driving Change*

[4] A desktop expert application built for a F50 client using 3400 nodes in an Expertool model would have required a spreadsheet with 240,000,000 cells and 80,000,000 mapping points to capture the same rules



MODELING HUMAN EXPERTISE

The ability to capture and reuse human expertise, i.e. build computational models of the expertise, requires understanding and replicating the expert problem-solving paradigm - the differences in the way experts and professional novices interact with information and knowledge.

Studies of syntactic, semantic, schematic and strategic differences between novices and experts in physics, computer science and medicine revealed the following common characteristics of experts[5]:

1. Rapidly and effortlessly recognize issues and anomalies
2. Work with mental models that connect observations and input
3. Manipulate large clusters of information based on context
4. Analyze and plan abstractly and consider many alternatives

The cognitive behavior of professional novices in each of the four above areas was the inverse – focusing attention on familiar details and choosing the most readily connected solutions. Therefore the experts' cognitive behavior needs to be modeled to capture the knowledge, and the novices' patterns to utilize it. This conclusion is in harmony with key lessons from decision modeling from AI research[6]:

- build a domain model first, and then define the executable model in terms of it
- reduce the conceptual distance between the modeling formalism and the way the user thinks

Modeling the cognitive behavior of experts is uniquely challenging because it requires software that does not limit expert users' ability to describe their mental models to the application designers' view of the world. They need the power to define qualitative, flexible contexts, as well as frameworks and rules for how information is interpreted as the contexts are evolved. Traditional KM software and data architecture cannot meet this challenge, since such applications are primarily designed for sharing content, the utility of which is dependent on the novices' ability to find it.

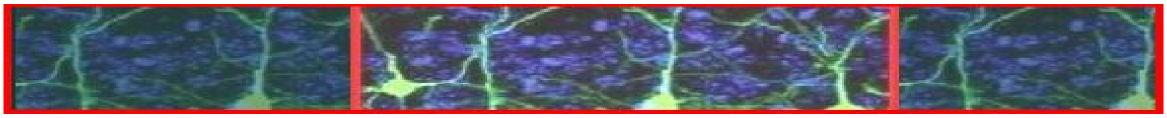
The Expertool platform addresses the above issues by the following methods:

1. Experts model their understanding of a problem domain rather than specifying problem-solution sets, objectively capturing their expertise
2. Potential elements and attributes of domain problem and solution candidates are linked by indication or elimination relationships
3. Relationships can be quantitative, qualitative or abstract
4. Links and relationships can be defined across domains and levels of abstraction
5. Modeling is point-and-click and expressions, eliminating translation-to-code errors and misunderstandings

---

[5] Mayer, R., 1992, *Thinking, Problem Solving, Cognition*, Freeman

[6] Klein, M and Methlie, L, 1995 *Knowledge-based Decision Support Systems,* Wiley



6. Independent input from diverse SMEs is integrated systematically, and then is reviewed, corrected and refined by multidisciplinary teams
7. Overlapping and conflicting links can coexist and interact, and the conflicts and issues made explicit

MODELING COMPLEX SYSTEMS

To begin modeling operations and systems within their environment as a complex system requires a significant departure from traditional computing approaches. After receiving a DARPA "Real World Reasoning" grant in 2008 to begin research in this area, IBM acknowledged, "Today's computers are powerful number crunchers but don't do a good job of dealing with ambiguities or integrating information from multiple sources into a holistic picture of an event."[7]

This lack of capability to build holistic models strikes at the heart of business survival. As stated in a McKinsey[8] analysis of the global financial crisis:

> The most important element of a strategy is a coherent viewpoint about the forces at work, not a plan.

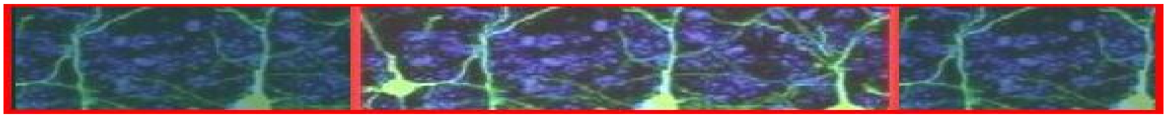
Without a coherent view of relevant forces and potential impacts as they behave in concert, scrupulous attention to planning and cost reduction can have unexpected and potentially grievous consequences. The systemic risk management requirements of Dodd-Frank are a response to this concern.

DARPA was promoting a biomimetic approach, and IBM together with its academic partners accepted the challenge to explore computing solutions that imitate the human brain. Three years later the first "neural chip" was announced[9] as the first step of an expected ten year path to biomimetic hardware. Hardware architecture, however, is not a critical success factor in modeling systemic risk and dynamic environments.

The brain does not store bits of information as if they had their own existence, nor does it "run programs"; it does something entirely different. As explained by Professor Pfeifer, head of the AI Lab at the University of Zurich (italics added), "Researchers now agree that intelligence always manifests itself in behavior -- thus it is behavior that we must understand, based on a synthetic methodology whose goal is - understanding by designing and building."[10] For example, observation didn't lead to an understanding of insect flight behaviors that seemed to defy the laws of aerodynamics, but replicating those behaviors in micro-robots did yield the insights which could be defined and applied.[11]

---

[7] **InformationWeek** **November 20, 2008** IBM Eyes Computers That Mimic The Brain
[8] *The* McKinsey *Quarterly* - DECEMBER 2008 • Richard P. Rumelt
[9] Scientific American, August 18, 2011
[10] Understanding Intelligence, 2001, Pfeifer and Scheier , MIT Press
[11] *Dickinson, Lehmann and Sane, 1999, Wing rotation and the aerodynamic basis of insect flight.*



The implication for systemic analysis and management is that we need to model the behaviors of the “forces” that interact with our organization and its processes and systems. We then need to watch the interactions and learn.

Unlike the deterministic methods to which traditional application engineering is limited of necessity, systemic modeling requires the coexistence of chaotic and stochastic model elements, as well as their ability to dynamically interact with the deterministic elements. From a cognitive perspective, the key principles for effective representation for complex domains are mature, and they are[12] :

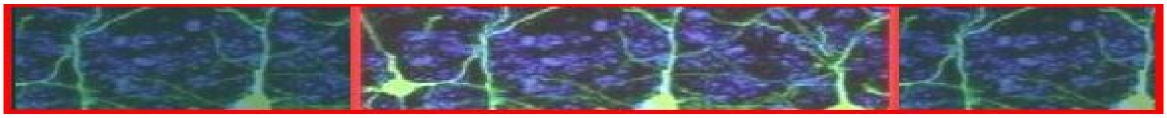
1. integrate levels of abstraction (CP-1)
2. combine globally homogeneous with locally heterogeneous representation of concepts (CP-2)
3. integrate alternative perspectives of the domain (CP-3)
4. support malleable manipulation of expressions (CP-4)
5. have compact procedures (CP-5)
6. have uniform procedures (CP-6)

While all knowledge engineering efforts seek to incorporate elements of cognitive science, a key aspect of the Expertool innovation strategy is the driving role of a cognitive architecture, which will be supported by appropriate information architectures. The Expertool modeling platform implements the above principles as follows:

- Each concept class has a cognitive state (Semantic, Episodic or Procedural)
- Each unique combination of keyword /cognitive state is a distinct class (CP-3; 4)
- The cognitive state of the concept class is defined at build time, and would then become an input to the concept relevance computation
- Each concept has a relevance state (Yes, No or Possible) which is computed at run time by a combination of defined links, data and user inputs (CP-3; 5)
- Each concept has a quantitative state, which is an array of populated and/or computed values (CP-4; 6)
- Concepts are linked to existing ontologies and taxonomies, as well as to an array of data sources (CP-1; 2; 3)
- The links within the neural network are determined based on a combination of available data and custodian inputs (CP-1; 2)
- Quantitative parameters affect relevance, and relevance affects quantitative state (CP3; 4)

The result of this approach is a toolset that not only facilitates agile design, but also dynamic experimentation and simulation.

[12] *P.C.-H. Cheng /Cognitive Science 26 (2002) 685–736*



Data Challenges

Much publicity has been given to the challenges of “big data” and the associated new opportunities. The chart below summarizes how key components of the methodology address critical data challenges.

	Mitigation Strategies						
Data Challenges	Neural Modeling	Rule Inference	Relevance Inference	Interaction Simulation	Cognitive Architectures	Conceptual Rationalization	Scenario Automation
Chaos	X		X	X	X	X	
Opaqueness		X		X			
Silos	X		X	X		X	
Complexity	X	X	X	X	X	X	X
Uncertainty			X	X	X		X

IMPLEMENTING AN EXPERTOOL KNOWLEDGE ENGINEERING SOLUTION

Data

While certain models may be prepopulated with proprietary or public domain content (e.g. Dodd-Frank legislation), the primary sources of data are flat file outputs from the client’s systems. The schemas from the source systems are replicated in the Expertool model, and then the data is imported without scrubbing.

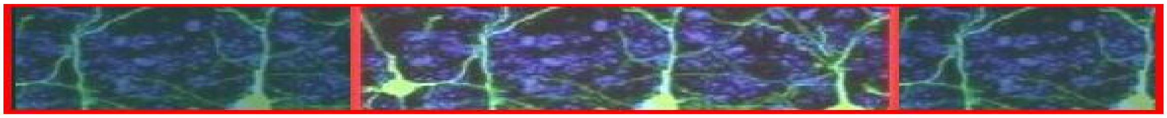
The model content is integrated and rationalized by a combination of:

- Automated and manual processes
- Standard and proprietary methods
- SME input

As long as the schemas remain stable, the data can be updated from comprehensive or delta flat files using a wizard or by automated feeds via the API as follows:

- Refresh the content
- Add new rows to tables

If the schema changes, a modeling specialist needs to make the adjustments.



Construction & Deployment

Models are constructed in agile iterations. The first iteration is a Prototype, built using sample core data and implementing one or more key functions. Generally, the prototype is scoped to enable project sponsors to visualize how the critical success factors and the fundamental business case will be achieved.

The prototype usually takes about 2-3 weeks to deliver, and typical projects range from six weeks to six months.

The primary output of the platform is a “model” – a flat file with all the content, links, rules, settings, formulas, etc., and the Expertool viewer is required to utilize the model (the neural network is constructed in RAM when the model is loaded into the Viewer). A license for the Expertool Viewer is included as part of your first knowledge engineering project. You can install the application on any computer that is owned by the client company.

Utilizing the Expertool Viewer, users can dynamically explore the data, perform complex analyses and simulations, provide expert input and generate reports.

The models can also be deployed on a .Net server, allowing other applications to access the implemented use cases.

Modeler software is sold separately. If a client wished to develop in-house modeling specialists, licenses and training are available.

INTELLECTUAL PROPERTY & THE EXPERTOOL PARADIGM

The Expertool Paradigm is also designed to enable new avenues for the creation of intellectual property. The model content is the intellectual property of the client who paid for its construction, whether it was built by internal or contract staff.

In addition to the software, the methodology used to create the model is proprietary to the Expertool Paradigm, and similar solutions may be built for other clients using their information and expertise.

If a client believes that the model constructed for them is a source of competitive advantage and would like an industry-exclusive license, it can be negotiated.

AUTHOR CONTACT:
joeglick@expertool.com

