COGNITIVE SENSEMAKING USING KEEL® TECHNOLOGY FOR INTELLIGENCE ANALYSIS

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Executive Summary:

Compsim's Knowledge Enhanced Electronic Logic (KEEL) Technology provides a new way to process information such that one can capture the expertise of an analyst and implement his/her human-like reasoning and judgment in computerized systems. Coupling human-like reasoning and judgment (right-brain functions) with conventional rule-based systems (left-brain functions) allow computerized systems to accurately model the analyst's interpretation of information. KEEL Technology is supported with a "dynamic graphical language" that allows the analyst to create, test, audit, explain and extend non-linear, adaptive interpretation of information for "sensemaking". Using KEEL Technology, one should be able to answer questions like: Is the issue economic? Is there a trade war on the horizon or are sanctions coming? Is the issue geographical? Are forces mobilizing on the border? Is war imminent? The models created using KEEL Technology are 100% explainable and auditable and easily extensible without requiring mathematicians or software engineers. Packaged cognitive functions (KEEL Engines) can be packaged for deployment in "any system architecture" for use in simulations. Behavioral models can also be deployed in autonomous systems. KEEL Technology is TRL 4-5.

Description:

The objectives of "intelligence analysis" (manual or automated) are to detect, interpret, and predict events, and sometimes to suggest actions.

Analysis and associated decision making are "active processes". This means that analysts have to interpret information in a dynamic environment. A piece of information may have little significance one moment and be extremely important the next. A piece of information may have no relevance to one decision or action, but may be a significant characteristic of another. This means that any automated solution must also allow the modeling of active information.

Analysts and decision makers are responsible for their decisions. This means that any automated solution must be auditable and explainable. While human analysts and decision makers are forced to use a written or verbal language (like English) to explain their reasoning, computerized systems can provide explicit value judgments (numeric weighting of information) to explain their analyses.

Numerous elements of analysis need to be supported: Politics (general)[1], Politics (personalities)[2], Link Analysis, Economics[3], History, Catalysts, Geography, Culture, Religion, Military[4], Impact of Science and Technology[5], and Change.

Reliability of information must be considered. [6]

Segmenting the Problem:

1. Collecting Material
2. Characterizing Information
3. Interpreting Information
4. Predicting the Future
    a. Scenario Planning / Testing
5. Policy Advise

Collecting Material:

A variety of means are already available to collect information; among them direct field intelligence reports, news media, internet, broadcast media, published information… This information is captured by some mechanism (outside the domain of this paper) and can be assumed to be stored on computer accessible media. This information is primarily unstructured textual material supported in some cases with graphics and images.

Characterizing Information:

Characterizing Information is the process of extracting context and valued information from the collected material. This is used to categorize individual information items and to establish an abstract value for that information. That abstract value can come from the raw material itself, from the source of the material, and from the age of the information (to name just a few). It may be appropriate to create adaptive policies to integrate quality drivers into the equation to more rapidly characterize the information. KEEL Technology can be used to create these adaptive policies (see KEEL Discussion later). Once information items are characterized they can easily be stored on a computer system for further interpretation.

Interpreting Information:

Information items cannot be interpreted in isolation. They must be interpreted in association with a defined problem domain (or analysis project). A single piece of information may be associated with many problem domains, but since the data is available on a computer system it can be reapplied over and over again. In this vein, consider that an individual analysis will assign its own modified values to information items. KEEL Technology supports the integration of valued information items that can be modified by other information items.

When creating models to interpret information one first must consider the possible outcomes of the analysis. Then one determines the pieces of information that may contribute to all of the potential outcomes. Then (using the KEEL "dynamic graphical language") one models how the pieces of information are integrated to impact the outcomes.[7]

Predicting the Future via Scenario Testing:

At *any instant in time*, all elements of an analysis are at an *instantaneous state*. Over time elements may be moving in different directions, but at any instant they are at that instantaneous state. Information items are exerting pressures on the system to move in different directions. Through the use of KEEL Technology, one can model and test the impact of changing information items as the models are being created; greatly shortening the development time. Standardized models can be stored and reused as the basis for future analyses. These models will define policies[8] for interpreting information.

A key characteristic required for next generation systems is to support the analyst's ability to "think" about the problem.[9] This means that a solution must allow the analyst to interact with the model and be able to determine whether it accurately describes what he/she intends. This is difficult with conventional approaches because the analyst must spend a significant amount of time translating the model from their mental image of how items are inter-related into some kind of script to be translated by the computer. KEEL addresses this issue by providing instantaneous response to new concepts so the analyst can get immediate feedback and make changes as appropriate.

Policy Advice:

The analyst's responsibility to suggest actions needs to be explainable. The very nature of KEEL Technology with interactive models makes it 100% explainable and auditable. One can clearly trace all decision and actions to "valued" information items. One can easily see how information items interact to make decisions or allocate resources. One can see how external entities are expected to react and can get explicit indications of risks or how outside influences might impact the future.

Decisions and actions can be reviewed (after the fact) to see how real-world events differed from projected events. This information can be used to tune the models, thus enabling them to be better and better, over time.

KEEL Technology [10]:

KEEL Technology targets the Information Interpretation and Scenario Planning / Testing phases of the analyst's activity along with any After-the-Fact review.

KEEL was developed to provide autonomous systems the ability to incorporate judgment and reasoning, thus allowing them to perform autonomous goal seeking according to human generated policies. To perform this function, the policies had to execute as well as, or better than, when executed by humans. Because they would be performed by "machines" they had to be 100% explainable and auditable (traceable to humans that defined them). An equally important driver was that ease of use was important, since the domain experts (analysts) were not likely to be mathematicians or software engineers.

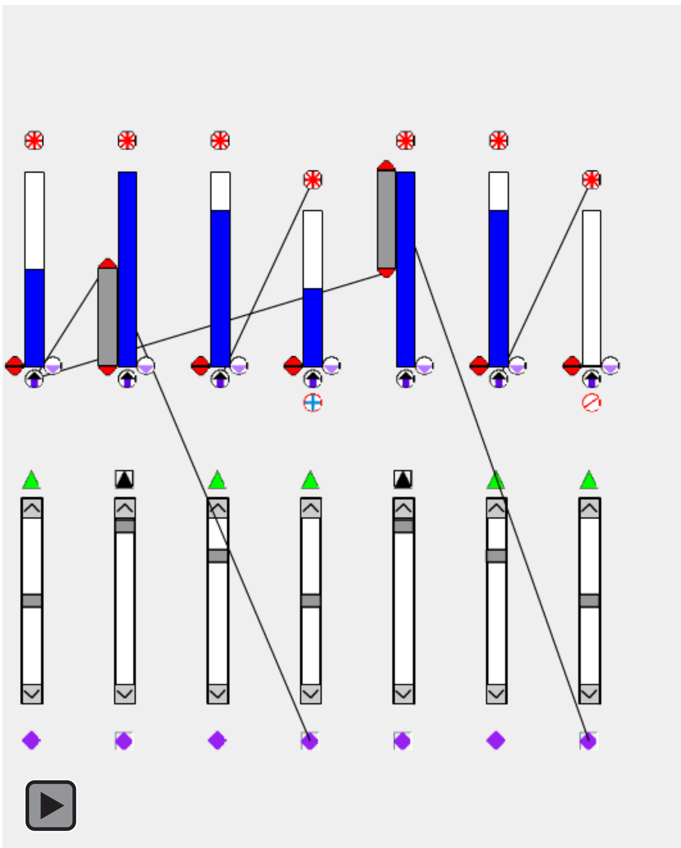

Figure 1

KEEL Technology includes 1) a new way to process information: much like an analog computer and 2) a new "dynamic graphical language" that allows one to model dynamic non-linear systems.

The KEEL "Dynamic Graphical Language" (DGL) is incorporated in the KEEL Toolkit. (Figure 1 shows an interactive example)

KEEL models are captured and executed as "KEEL Engines". The KEEL Engines are created with the KEEL Toolkit as text files (source code functions in C, C++, C++.NET, C#, Flash ActionScript, Java, JavaScript, Octave (MATLAB), Python, Visual Basic, VB.NET and a few others) that can be integrated into any platform or system architecture.

Model development within the KEEL Toolkit is interactive and dynamic. (See Figure 1: Manipulate the vertical scroll bars identified as 0, 1 and 2 and see the system respond. This simple model was deployed as Flash ActionScript for embedding in the pdf file.) The analyst drops icons representing information items on the screen and they become immediately part of the interactive analysis. The KEEL Toolkit can even take real-world data into the analysis during the development process.

A variety of techniques can be used when the models have been placed into a simulation system to assist in the evaluation phase. One analytical tool is called KEEL language "Animation". This is where real-world data can be sent to the KEEL Toolkit where the language is animated (so one can "see the model think"). Decisions and actions in a real-time environment can be trapped for auditing and further investigation.

Requirements as stated by the United States Intelligence Advanced Research Projects Activity under the Director of National Intelligence:

- **Is implemented within a computational framework –** KEEL is architecture neutral and can be deployed on any platform since the cognitive models are implemented as low level functions in C, C++, C#, Flash, Java, Octave(MATLAB), Python, Visual Basic (and others)
- **Captures key human sensemaking behaviors, including failure modes –** The interpretation of information is an analog right brain process of integrating all information that is available. One can easily include modes of human failure in the models (lack of attention, failure to perceive, limited short term memory, or poor judgment). It is also easy to integrate psychological characteristics into the models.
- **Is scalable, i.e., is not limited to toy problem sets but rather can perform sensemaking over a large, heterogeneous body of data-** There is no real limit to the complexity of KEEL models, although it is often beneficial to break complex models into multiple KEEL Engines from an ease of understanding standpoint.
- **Is grounded in our current understanding of the cognitive architecture of the human brain[11]** – The human brain is a network of interconnected neurons trained by observations and executed by pattern matching. KEEL is also a network of interconnected information items. The difference is that the analyst defines the network relationships in a manner that can be explained and audited. Adaptability (at any level desired) can be integrated into the network. It is recognized that portions of the brain remember different patterns. It is likely that one would build separate KEEL Engines to interpret different problem domains.

Summary:

KEEL Technology provides the next generation of embedded intelligence that is suitable for intelligence operations[12] where one needs to be able to package analytic techniques that can be explained, reused, corrected and extended over time

Reference Material:

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[1] KEEL Demonstration; Pre-emptive Military Attack;
http://www.compsim.com/demos/d20/d20.htm

[2] KEEL Demonstration; Human / Event Profiling;
http://www.compsim.com/demos/d40/Profiling1.html

[3] KEEL Demonstration; Stock Market;
http://www.compsim.com/demos/d5a/stockmarket.html

[4] KEEL Demonstration; Group Behavioral Modeling;
http://www.compsim.com/demos/d48/GroupModeling1.html

[5] Compsim; "Characteristics of Innovation";
http://www.compsim.com/papers/Characteristics%20of%20Innovation%20(KEEL).pdf

[6] Wheaton, Kristin; "Warning Solution – Intelligent Analysis In The Age Of Information Overload"; Publisher: Fairfax, Va.: AFCEA International Press, 2001. ISBN: 0916159302 DDC: 658.4038 pg7

[7] Keeley, Thomas; "Where to Go – What to Do";
http://www.compsim.com/papers/Where%20to%20go%20What%20to%20do.pdf

[8] Keeley, Thomas; "KEEL Technology for Intelligent Policies";
http://www.compsim.com/papers/KEEL%20Technology%20for%20Intelligent%20Policies.pdf

[9] Paraphrased from comments by Dr. Jacqueline Henningsen (Director, Air Force Studies and Analyses Agency, Office of the Vice Chief of Staff) at the 2007 NTSA DOD Modeling and Simulation Conference in Hampton, VA, May 2007

[10] Compsim; "KEEL Technical Introduction";
http://www.compsim.com/papers/KEELIntro032007.pdf

[11] Compsim; "Mathematics of the Brain using KEEL Technology";
http://www.compsim.com/papers/WhitePaper_DARPA-BAA-08-65%20Mathematics%20of%20the%20Brain.pdf

[12] "Auditable Intelligence Wins"; http://www.compsim.com/papers/Position%20Paper%20-%20Auditable%20Intelligence%20Wins.pdf