Knowledge Enhanced Electronic Logic for Embedded Intelligence

The Problem

Systems (military, network, security, medical, transportation…) are getting more and more complex. In future systems, assets will not necessarily be commanded directly by humans. The assets themselves may be autonomous or semi-autonomous software agents or devices (machines). At the same time humans must retain control of those assets.

In this new environment, machines (software and/or hardware) will need to be able to interpret policies that were previously interpreted by humans. The use of "English" written or spoken language will not provide "sufficient" detail for machines to provide this service. In the present factory automation market, distributed machine control is commanded by exchanging variables with explicit values. Programs are executed to utilize these values to produce products and services. Unfortunately the machines and software agents in the future will not be bound to the factory floor. These machines must address complex (dynamic, non-linear, interactive, multi-dimensional) problems. These machines (and software agents) will still need explicit judgment and reasoning capabilities (policies) to control their actions. IF | THEN | ELSE logic will not be cost effective to develop to provides the necessary level of service.

Technology Overview

What is it?

Compsim's KEEL® (Knowledge Enhanced Electronic Logic) Technology can be used to put human-like decision-making in devices or software applications. KEEL Technology can be considered an "expert" system that uses the decision-making skills of a human as the basis of judgmental decisions. The KEEL Toolkit provides the mechanism to collect and test those reasoning skills before deployment in the final product.

KEEL Technology allows Subject Matter Experts to model and deploy their reasoning (decision-making process) in applications and in devices without extensive support from mathematicians and software engineers. When deployed, systems can dynamically adapt to the environment (make or suggest decisions and/or actions).

KEEL is:

- A development environment including the KEEL Dynamic Graphical Language
- A model for accumulating supporting and objecting arguments in order to make a decision or take an action
- A small footprint engine that processes sensors or other inputs according to the design of a system created in the development environment
- A method for implementing the cognitive model as an analog circuit

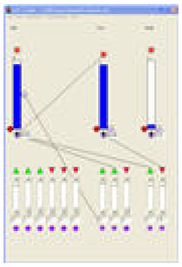
Some example areas where KEEL can be applied:

- Human experts are required to interpret information to make the best decisions or take the most appropriate actions
- Devices must operate autonomously and make judgmental decisions on their own
- Devices can make control decisions when human operators are not present
- Repetitive judgmental decisions are prone to error
- Judgmental decisions by trained operators are potentially “tricked” into overlooking critical attributes
- Human experts take too long to make judgmental decisions
- There is significant cost associated with training new “human” experts / expert operators to perform repetitive tasks
- Applications where the judgmental decisions must be explained
- Complex situations where it is uneconomical to develop and maintain straight line code (IF, THEN, ELSE)
- Situations where the environment is dynamic and the importance of information changes and the system must react to change
- Situations where there is an advantage to be able to create one design and execute it on multiple platforms: device, software simulation, web
- When the small memory footprint of a KEEL engine is an advantage
- Where architectural issues may prohibit other solutions (KEEL technology is architecture independent: localized, distributed, web based, multiprocessor…)

Why is KEEL special?

Using the KEEL toolkit, a human (i.e., a SME “Subject Matter Expert”) can document how to analyze problems and take actions. The resulting code can be embedded into a device, a software application or demonstrated on the web. Special characteristics include:

- Decisions and/or actions are easily explained
- Graphical development tools focus on subjective “right brain” reasoning
- Generating a small memory footprint makes it possible to add human like reasoning to very small devices
- Interactive development environment allows the designer to get immediate feedback in the reasoning process
- A single design can be deployed in a variety of environments
- Architecture independent (simple stand-alone applications, client-server, distributed)
- Easy to integrate into existing systems (simple API)



Interactive Demo:

(Click the image)

How does it work?

The KEEL Toolkit allows an SME to interactively model a decision-making or control process. The designer receives immediate feedback from the design, as the information interpretation process operates while the design is being created.

A variety of tools assist the designer in documenting the model. When the design is ready to be integrated into the final product, it is translated from the graphical model to conventional code (Flash Actionscript, C, C++, C++ .NET, C#, Objective C, DART, JAVA, JavaScript, Octave (MATLAB), Python, SCILAB, Visual Basic, VBScript, and PLC Structured Text in a variety of wrappers for different development environments) that can be provided to the software engineer for system integration. The isolation of the decision-making model from the native source code simplifies maintenance. If an auto-generated logging function is integrated into the application, any decision that is logged can be read back into the development environment so decisions or actions can be reverse-engineered (easily auditable).

KEEL Technology attempts to mimic the way that humans balance input information to make decisions and allocate resources. In this manner, a KEEL engine operates like an analog computer. It accumulates supporting information and balances this with objecting or blocking information. Individual considerations interact with other decisions or actions in a web of relationships that are balanced to achieve the best overall set of actions for the system. In a KEEL system, the importance of information is likely to be constantly changing. During development the designer is getting immediate feedback. This allows the designer to make changes rapidly (without translating concepts to formulas and code before seeing the impact of those changes).

The importance of information can be controlled from external events or can be controlled as part of internal processes.

The outputs from a KEEL engine can be

- Discrete (YES/NO or ON/OFF or Do Something / Withhold from Doing Something),
- Mutually exclusive option selection (A, or B, or C…),
- Relative resource allocation types (do X amount of Action 1 and Y amount of Action 2…).

All based on the integration of “valued” information.

Events can be triggered. The number of inputs and outputs from a KEEL engine are limited only by the resources available.

The output of the KEEL Toolkit is two or three small subroutines and a series of tables that define values and relationships between information. There is no textual processing in the KEEL engine itself, only an information evaluation process. The auto-coded KEEL “code” is delivered as a text file, where the code can be inserted into the user’s development environment for a system build. Any display and control functions are defined external to the KEEL cognitive engine. The KEEL Engine provides the information fusion component. A system may have numerous KEEL Engines. KEEL Engines might operate independently, or may be part of a hierarchy of information fusion functions.

Competitive Technologies:

Unlike neural nets and fuzzy logic, the KEEL logic can be easily visualized and explained. The use of a pattern matching approach to cognitive solutions could present a problem when it is important to validate the decisions or actions. With pattern matching there is no “reasoning” taking place other than to suggest that there is some degree of a matched pattern. When patterns are similar, but not the same, there is a risk that the wrong choice is made purely because the patterns are somewhat similar. A mechanism that uses an organized *process* is more likely to give a correct response.   KEEL technology provides such a process.

Technology Comparison

	Neural Nets	Fuzzy Logic	Bayesian Belief Nets	AI – Forward / Reverse Chaining	KEEL
General Concept	Pattern matching	Geometric Fuzzification / Defuzzification	Probabilities of Probability	Trial and Error	Dynamic adjustment to Importance of data (genetic)
Source of Understanding	Patterns	Human Designer	Human Designer / Statistics	Human Designer	Human Designer
Pattern Training Required	Major Problem	No	No	No	No
Explainable Decisions	No	Difficult	Difficult	Somewhat	Easily Explainable
Small Memory Footprint	No	No	No	No	Best
Performance	Determined by application	Determined by application	Determined by application	Worst	Determined by application
Suitable for Control	Yes	Yes	Probability not	Probably not	Yes
Interactive Development	No	Maybe	Somewhat	Maybe	Yes
Portable design (device, software, web)	Probably Not	Probably Not	Probably Not	Probably Not	Yes (one design, many output formats)
Weaknesses	Pattern training required; Decisions not “explainable”; Does not handle “surprise” conditions	Difficult to explain reasoning; Somewhat arbitrary design concepts	Statistics may not be available for non-linear systems; Difficult to explain	Fragile / brittle- hard to maintain; Does not handle “surprise”	License required

Technical Basics

KEEL Technology:

- Utilizes a “network” of information items (web of relationships)
- Accumulates support and blocking mechanisms like exciting and inhibiting synapses in the brain
- Separates the cognitive processing model from the problem definition
- Creates an analog accumulation of the support and blocking signals that can define the strength (or importance) of the output
- Does not utilize pattern recognition, which would require pattern training, but is based on policies defined as relationships between actions (or decisions)
- Utilizes a human expert to define the relationships between information and to validate the reasoning model, thus humans retain control of the policy
- Allows analog inputs to define relative or valued information as inputs to the architecture
- Does not blur the data with a fuzzification / defuzzification process
- Easily auditable so decisions and actions can be traced to root cause
- Creates a solution that can be reviewed and understood by humans (without support of mathematicians and software engineers)
- Creates decisions and actions that can be explained or recreated based on logged data. (Note: the process is explainable because all relationships are visible using the KEEL Toolkit)
- Allows any idea to interact with other ideas

Potential Applications:

KEEL technology can be applied in: Military, Automotive, Governmental, Medical, Industrial Automation, Home Automation, Homeland Security, Financial Systems, Enterprise software, Semiconductor, Network Management, and Electronic Gaming markets.

- Military
  - Unmanned Vehicles
  - Autonomous Systems
  - Intelligent Weapons
  - Actionable Rules of Engagement and Policy Execution
  - Command and Control Automation
  - Data Fusion / Information Interpretation
  - Portable Training Tools
  - Diagnostics / Prognostics
  - Adversarial Profiling / Behavioral Profiling
  - LVC Gaming
  - Modeling and Simulation of Complex Systems
  - Electronic Warfare
  - ISR Systems
  - Augmented Command

- Automotive
  - Telematics
  - Attentive Systems
  - Diagnostics / Prognostics (localized, distributed, global)
  - Factory Test
  - Adaptive Control
  - Embedded Maintenance
  - Fleet Management

- Governmental
  - Economic Modeling
  - Political Modeling
  - Adaptive Regulations
  - Adaptive Policies
  - Auditable and Traceable Decisions and Actions

- Medical
  - Intelligent Medical Equipment
  - Embedded Treatment
  - Equipment Diagnostics / Prognostics
  - Automated Information Analysis

  - Adaptive Prosthetics
  - Patient Monitoring
  - Personalized Medicine

- Industrial Automation
  - Diagnostics / Prognostics
  - Intelligent Work Flow
  - Automated Asset Management
  - Supervisory Control
  - Holonic Manufacturing
  - Intelligent Agents

- Home Automation
  - Diagnostics / Prognostics
  - Security Systems
  - Adaptive Homes

- Homeland Security
  - Airport Security
  - Automated Supervisory Control
  - Objective Information Analysis
  - Profiling / Modeling
  - Autonomous Robotic Policing

- Financial Systems
  - Explainable Loan Approval
  - Objective / Explainable Insurance Pricing
  - Objective Stock Brokerage Analysis
  - Economic Modeling
  - Adaptive Investing
  - Adaptive Regulations

- Enterprise Software
  - Data Mining / Analysis
  - Resource Allocation / Load Balancing
  - Augmented Management
  - Adaptive Autonomous Policies

- Semiconductor
  - Resource Allocation
  - Custom Circuits
  - Behavioral Circuits

- Network Management
    - Resource Allocation
    - Network Diagnostics
    - Cybersecurity

- Electronic Games
    - Unscripted Games
    - Intelligent Toys
    - Autonomous Toys
    - Adaptive Toys
    - Educational Toys and Games

Contact:

Compsim LLC is a provider of next generation cognitive technology for application in automotive, industrial automation, medical, military, governmental, enterprise software and electronic gaming markets. The company is headquartered in Brookfield, Wisconsin.

Compsim LLC
PO Box 532
Brookfield, Wisconsin 53008
(262) 797-0418
http://www.compsim.com