Why It's Time for Devices to Think

Knowledge Enhanced Electronic Logic™

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Objective

When we compare computers to decision making as performed by humans, we can differentiate the process by suggesting that humans solve problems while computers execute programs. When humans solve problems they consider a broad range of issues and consider the importance of one issue while deciding on another.

Since computers have been invented, the primary functions have been to accumulate data, transform the data (add / merge / select / delete) and then supply the same data in a new format back to the user. Computers have benefited the economy by executing the same program faster and faster. Computer programming (software) was developed to direct the operation of the computers. Object oriented programming was created to simplify programming by structuring computer programs like physical devices. Microprocessors were developed to add functionality to devices. Like the original mainframe computers, the microprocessors initialize the variables and then execute a loop. In the loop, variables are loaded from external sensors and manipulated or transformed in order to create output values, which are used to control external systems. Microprocessors, desktop computers and mainframes have consistently operated on human created programs that execute a sequential set of transformations.

This paper considers how humans accumulate knowledge to make decisions and then discusses how computers can perform the same reasoning activities. It covers Knowledge Enhanced Electronic Logic™ methodology for creating a product architecture that can make subjective decisions.

Contents

Description of Human Decision-Making

Everybody makes decisions: as part of a job, during recreational activity or hobbies, during personal activities, around the house, or traveling from place to place. To perform almost any activity requires skills in decision making. There are only a very small number of functions performed by human beings that do not require conscious thought. Blinking eyes, breathing, beating heart and reflex actions are a few actions that are

automatic and do not require conscious decision making. Most other decisions are made based on the information available at the time. Sometimes people make decisions without all the necessary knowledge or understanding. A baby may reach into a fire if it doesn't know that fire is dangerous. People make mistakes when they make decisions without understanding all of the aspects of the issue. People learn from their mistakes as they go through life. Some of these mistakes are costly, however.

To avoid making costly mistakes, people go through training to get an education and also learn through the normal experiences of life. Training is provided by the community education system and through on the job training. On the job training may focus on the specific job to be performed: operation of a piece of equipment or how to run a computer program. Training can also be used to educate an employee on the business drivers and ethics that should help the employee make decisions while performing a job function.

Whether we're aware or not, we 'people' rely on knowledge, emotion, anxiety, frustration, fear, and input from others to make decisions. The human body supplies adrenaline to heighten awareness while making decisions. These animal instincts may have been inherited to help an individual survive. Many times some of the emotional reasons for decisions can outweigh more objective reasons.

While business decisions should be made objectively, the pressures of daily profit and loss and organizational conflict may cause more subjective decisions without looking at all aspects of the problems. Frustration and politics can even contribute to subjective decisions while operating equipment on the factory floor. These subjective decisions made without looking at all aspects of the problem cause safety problems, production issues, and reduced efficiencies across the organization.

People and organizations go through continuous training in most companies. The objective is to avoid subjective or emotional decisions while on the job. Training alone, however, seldom creates experts overnight. It takes the failures or checkpoints along the way along with the successes to get to the state where decisions are almost always or most often correct.

The Creation and Use of Experts

During the normal course of individual activity (on the job or away from the job), people fall into their level of comfort. They develop their level of capabilities where they balance their skills against the risks of failure. This is determined by rewards and penalties accumulated along the way. There are times when an organization needs skills beyond what exists in their workforce. A call is made to experts to solve those special operational problems that cannot be addressed with their existing workforce.

Experts gain their knowledge through training. The training may be more extensive than for a normal worker. Their knowledge can also be obtained through experience. Where a normal operator or decision maker may have general knowledge about a domain, the expert will have the knowledge about all the problems that can occur. It is often this

knowledge of all the potential problems that differentiates the expert from the average workers. Usually experts develop relationships with other domain experts to extend their knowledge base. The expert also maintains an understanding of potential solutions and how each of the solutions can respond to the different problems. There is often a balancing between solutions where the expert evaluates cost, risk and benefits to make the optimal decision or recommendation. When experts analyze a number of symptoms of a problem, they can evaluate the importance of various symptoms to determine which ones are the most important and which ones play a less significant role.

There are several problems with employing experts. They are often expensive. They may not be available when they are needed. And they may not be experts at all. There is no real validation that will guarantee that an expert is really an expert or that one expert can solve the particular problem encountered. Some companies provide field service experts to solve problems that their customers encounter while installing and using their products. To meet market needs, these companies have to hire new employees and train them. Training alone may not create a real expert.

Product Suppliers

Product suppliers provide solutions to problems in the form of packaged solutions. They attempt to identify user needs and package a solution in a physical product. They sell the customer the product to satisfy the need or problem. Product suppliers spend time understanding the needs of the customers. They attempt to become experts in the customer's problems to create the best solution.

Product Suppliers build products that take input from the environment and respond with a solution. Inputs could be from external sensors that monitor a process, sensors that monitor the status of a machine, sensors that monitor the quality of the input material, or sensors that monitor scheduling information. The inputs could come from an operator, or they could come from enterprise systems in the form of scheduling information or the inventory of available parts.

At times, after the products are put into production, the customer encounters problems with the system. They contact the Product Supplier for an explanation of how to fix the problem. Product Suppliers offer telephone support and field service personnel to help customers respond to problems encountered in the field.

Some system problems are related to performance and quality. A product or process expert is often required to optimize the system as the environment changes; changes in material, changes in quality, changes in machine performance, for example. Product suppliers are often called in to help companies solve these product and process issues.

Like most commercial suppliers, when a product supplier offers their expertise to solve customer problems they are providing the expertise as a revenue producing activity. And

like other experts, they have their individual levels of expertise that may or may not be able to help with the system problems.

Knowledge Enhanced Electronic Logic Concepts

The concept of Knowledge Enhanced Electronic Logic responds to an evolutionary change in computing technology. This is happening as computers change from data transformation tools to tools that makes subjective decisions in the same manner as human beings. So unlike computer programs that perform a sequential series of instructions that have been programmed with sequential logic, KEEL technology solves multiple inter-related problems recursively. Compsim's patent pending methodology simulates the decision-making capabilities of human beings.

KEEL technology uses a weighting and balancing technique. It accumulates supporting information for each issue that is part of the entire problem domain. It then offsets the accumulated support with accumulated objections. KEEL technology is based on the concept that all reasoning starts with a potential decision that can either be supported or denied. There is nothing more positive than 'yes' and nothing more negative than 'no'.

When a person accumulates the reasons for supporting a decision, the reasons can be absolute, weak, or any place in between. Similarly, objecting reasons can range from absolute to weak. While one may have one strong reason for supporting a decision (or one thousand strong reasons), the decision cannot be more positive than just 'yes'. Humans can get emotional and jump up and down and say yes, yes, yes, but it's still just 'yes'.

A decision with lots of strong support can be completely offset with an absolute rejection. For example, while a proposed solution may offer many positive aspects, if it violates the laws of nature, then it cannot be a viable option. The decision to purchase a lottery ticket might fall into a similar category. One might dream of a hundred great things that would happen if the lottery was won. The negative would be the chances of winning. Not many companies would want to run a business by betting on the lottery. On the other hand many lottery tickets are sold.

KEEL technology also considers the inter-relationships of multiple decisions and how one decision may impact other decisions. Most decisions cannot be made in isolation, so it is important to consider how decisions in one area impact those in other areas.

KEEL Toolkit

The KEEL toolkit provides a mechanism for describing complex problem domains where a decision-making process requires the analysis of multiple separate and inter-related issues. The KEEL toolkit provides a mechanism for taking a problem structure from Compsim's business management tools that provide knowledge capture and organizational decision-making support. The information from this tool set can be imported into the KEEL development environment. The KEEL toolkit also provides its

own graphical mechanism for defining problems with associated supporting and objecting inputs.

The toolkit provides a graphical method for defining multiple problems as part of a complex system, where the decisions to one problem can impact other decisions.

The KEEL toolkit provides a mechanism for using the analysis of one problem to control the importance of another problem as part of a larger system. For example: where Decision A is tied to Decision B, and Decision B is tied to Decision C.... Decision A impacts Decision B, which impacts Decision C. One company may choose to purchase another company to add a new product line. That decision will potentially move discretionary funds in one direction that will have a negative impact on some other business situation. A person may choose to take a vacation instead of making an investment. The person is balancing the enjoyment of the vacation against the long term value of the investment. A machine tool may choose to slow down (reducing productivity) in order to run longer. Or a pump may choose to pump water to put out a fire, rather than pump cooling water to a computer system.

The KEEL toolkit supports the concept of thresholds. In this case, the support for a decision can be measured in strength of conviction (confidence or value modified by supporting and objecting arguments). Thresholds can cause events. In the case of an embedded or automated system, thresholds provide a trigger mechanism for performing discrete events: warning the user; turning on and off control signals.

The KEEL toolkit provides a mechanism for using thresholds to control other decisions: Causing them to be active or blocking them from impacting the system. For example: The temperature of water in a tank is relevant only if there is water in the tank.

The KEEL toolkit automatically generates Visual Basic code that can be pasted into Visual Basic applications to create solutions with embedded expertise. The Visual Basic code produced by the KEEL toolkit can be used as pseudo code for implementation in any programming language. Because of the simplicity of the code created, it should take less than a day to integrate the design created with the KEEL toolkit into any programming language.

The KEEL toolkit provides a simultaneous development and emulation capability. This allows the domain expert to get immediate feedback from the decision-making design without going through a compile and debug phase.

The KEEL toolkit has a built in analysis feature that monitors the design for potential unstable designs. An example of this would be feedback loops where Decision A impacts Decision B, which in turn, impacts Decision A.

The KEEL toolkit provides a mechanism for graphing the relationships between inputs and outputs. This allows for a user to review the details of how individual decisions will be structured over a range of input values.

The KEEL toolkit provides several reports that describe the decision making structure created by the user.

Description of sample applications

Military - Smart Weapon
A drone aircraft could be told to go find targets and destroy them. In performing this task, the aircraft will watch for threats, look for targets, evaluate the value of targets, balance the risk of going after the targets with their value, look for hiding places (if it is threatened), monitor its weapon capability, decide when to attack, retreat, hide and scout...

Electronic Games
Animatrons are the graphical entities that game players compete against. Using the KEEL engineered decision making, the animatron will be able to think on its own by monitoring its environment (just like the player) and decide when to attack, when to hide, when to look for food, who to attack...It can decide how to react when certain of its capabilities are destroyed (weapons, maneuverability, reduced energy...)

Medical Instruments
A diagnostic tool can evaluate inputs from several sources while evaluating a patient complaining about chest pain: the examination by the physician, data supplied by the patient, test results and evaluations from multiple instruments, and can suggest other needed tests or make a diagnosis based on the abilities of an 'embedded' expert cardiologist

Automation Equipment
A cell controller could take inputs from several products and sensors and optimize performance of a work cell. Vibration, temperature, pressure, torque, current, flow, speed, quality... can be monitored and interpreted in order to make decisions on controlling input variables and calling for repair. The decisions could include information on replacement inventory or access to alternative solutions.

Insurance underwriting
The KEEL engine could evaluate input data and decide how to underwrite, structure, or rate an insurance policy. This could allow the user to determine what levels of coverage can be offered for what amount of money.

Training
The KEEL toolkit can be used as a general training tool to teach subjective decision making, where situation modeling can be created in a dynamic environment. It can also

allow trainees to practice skills or try alternate solutions in a safe environment, such as airline pilot training or medical education.

Compsim LLC is a provider of next generation decision-making technology for application in industrial automation, medical, military, governmental, enterprise software and electronic gaming markets. The company also provides consulting services using its advanced technology to solve tactical and strategic business problems. The company is headquartered in Brookfield, Wisconsin. The website is: http://www.compsim.com

