KEEL Technology Applied to Highly Distributed Loosely Coupled Systems

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Abstract

Highly-distributed loosely-coupled systems are applied to complex systems when there is a need to insure that the systems continue to operate, even when portions of the system are disabled. The creation of loosely coupled systems involves a mechanism for communication and synchronization between segments and a mechanism for the individual segments to operate with some level of independence. This report focuses on the semi-autonomous behavior of the individual operating segments. There is a need for the creation of solutions that create fully explainable actions in order for the system to be audited and tuned by human observers. This report suggests a design methodology that allows the designer to visualize system operation during the creation of a set of adaptive rules. It is offered as an alternative to hard-coded solutions, neural and fuzzy solutions or conventional AI techniques.

1. Problem Statement

Semi-autonomous devices in loosely coupled systems are often packaged to perform specific tasks or to encapsulate specific abilities. Their behaviors are often selected for resilience and their abilities to react to changing demands. The application component of these devices is responsible for responding to the objective of the entity. This application segment operates on a set of "logic functions" that define its performance. Applications for many devices have been created using conventional programming languages with If, THEN, ELSE logic statements. There are some problems, however, where conventional logic is impractical to develop. Pattern matching solutions may be viable. They can be used to observe complex data patterns and be trained on how to respond. These might be termed the cognitive areas, where the device is asked to make "reasonable" decisions or take relative actions. A key aspect of these judgmental decisions is the ability to interpret information. This interpretation is often performed by determining the importance of information items relative to specific views of the problem domain. A single piece of information can have different levels of importance with respect to different parts of the same problem. These types of problems may be the most complex. The solutions involve addressing multiple problems simultaneously to achieve a system solution that is most advantageous for the complete system. When the problems are addressed with conventional logic they can be "explained" in human terms. Development, however, is difficult. Using neural nets or neuro-fuzzy solutions one can create repeatable solutions when appropriately trained, but they are not always "explainable" when reacting to untrained situations. This paper suggests that an alternative solution is desirable when there is a need to respond to a dynamic environment and create explainable responses that can be fully audited by humans. Auditing and tuning semi-autonomous devices are critical activities when these devices incorporate subjective decisions. With today's technology it may be unacceptable to allow these decisions to be made through totally artificial techniques.

2. Proposed Solution

The proposed solution creates a rule-based heuristic reasoning system for packaging cognitive rules in embedded products.

2.1 Concept

When humans make judgmental decisions that involve multiple domains, they *balance* the impact of different actions until they determine that they are choosing the best overall response. When humans make these decisions they are dealing with information from a variety of sources. A single piece of information may impact different parts of the overall

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problem domain with differing levels of significance. When making subjective decisions, humans are also considering time and space impacts to the problem domain. Future issues may have less impact than immediate problems. In this paper we propose packaging heuristic reasoning into cognitive engines that can interpret information from a variety of sources: including humans, sensors, databases, or any other cognitive process (local or remote). We propose a solution that graphically documents the dynamic importance of information items and the relationships between those items in order to make judgmental decisions or take relative actions. Because the importance of information is dynamic, the rules are dynamic which allow the systems to adapt to their environment.

2.2 Technology

The proposed solution allows judgmental rules to be defined using graphical source code language, where inputs either support or block a decision (or action) and where the importance of a decision (or action) is indicated by the size of the graphic representation. Relationships between actions are defined by "wiring" the information items together. Connection points describe the type of relationship and they can trigger events or set relative values. The relative values can determine the importance of information. When the system processes the supporting and blocking inputs a relative answer or action is determined for each decision point. This decision then propagates throughout the entire cognitive domain.

2.3 Implementation

When implemented as a cognitive solution, the graphical rules are translated into conventional source code. This includes a small amount of processing code and associated tables that define the importance of information items and the relationships between them. When designing loosely coupled systems, a hierarchy of command and control is designed that defines how a superior device can modify the decision-making rules of the subservient cognitive engine. These commands function just like any other input data item to the engine and cause the cognitive engine to adapt to the external directives.

3. HASE Related Elements

In loosely coupled systems with a hierarchy of command and control, the superior device depends on the subservient device to make judgmental decisions according to the rules it has been assigned. This offloads the superior device from the responsibility of interpreting all of the information available to the subservient device. Because the subordinate object is still operating as an autonomous object in a loosely coupled system it is still making decisions on its own. It is only by dynamically changing the rules that the controlling object changes the behavior of the subordinate object. In loosely coupled systems it is also important to design the system to support rejection or failure by peer or subservient objects. Because autonomous functionality allows for local decisions, a device will be making its own decisions about how to respond to commands. Commands from above can be rejected because of local observations, which may include recognition of local hardware failures, for example. While failure support is not necessarily different from any good system design, one needs to provide more care in the design of loosely coupled systems.

It is our opinion that the design of a highly distributed loosely coupled system cannot be viewed only from the execution environment. It must also take into account the development environment. In the development environment, the design process must allow for incremental testing and evaluation, especially with regard to the subjective decisions that must be made. In the execution phase there must be a way to evaluate the cognitive performance. This is especially true in complex situations that were never considered when the system was designed. One of the advantages of any rule-based system is that the decisions can be reproduced and decomposed.

4. Conclusion

Judgmental decisions can often be required in the development of autonomous or semi-autonomous agents or devices that participate in loosely coupled systems. The proposed methodology creates solutions that can be explained and audited by humans. The small footprint makes it applicable to small embedded applications. KEEL® (Knowledge Enhanced Electronic Logic) technology is suggested as an alternative to neural nets and fuzzy logic based solutions when auditable actions are required.