REPRESENTING COLLABORATIVE MULTI- KNOWLEDGE AGENTS AS GENERIC RULES

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ABSTRACT

This paper discusses the internal representation of a multi-knowledge agent decision support system that was developed for building thermal design. The system is able to provide designers with specific problem detection in thermal design without the use of rules of thumb. The paper describes how generic rules can be used as virtual agents and how these agents can interact using a blackboard model. The generic rules utilized use logical variables as a strategy to capture generality. This allows the rules to deal with variables that can be replaced by any possible term. In addition, it allows the rules to be equivalent to the infinite set of rules that could be obtained if the variables were replaced in all possible ways by terms. In the system, these terms include the building elements and systems that affect the thermal behavior of the building. Problems associated with agent conflicts and how they were resolved in such a model are described.

1 INTRODUCTION

Knowledge is a crucial part of AI systems. In systems that contain knowledge as part of their structures for reasoning, the way this knowledge is represented internally in the programs is fundamental to solving these reasoning problems. This internal representation in the form of syntactic and semantic conventions of describing things is what is referred to in the field of AI as knowledge representation (Bench-Capon 1990). Some knowledge representations allow more powerful control strategies to operate on them than others. That makes it important to select the appropriate representation for the specific problem solving task (Nilsson 1980). Because of the lack of a single method that can optimize the capability of all kinds of knowledge, several knowledge representations exist. Some of these representations include: predicate logic, production rules, statistical reasoning representation, semantic nets, frames, and conceptual dependency. This paper discusses a rule based representation used in a system that has been designed to search for potential thermal problems in buildings without the use of rules of thumb.

Previously, several research projects focused on providing heuristic knowledge for approximate evaluation that aids in the conceptual to intermediate design stages for building thermal problems (Shaviv et. al 1992, 1996). This approach takes advantage of the knowledge engineering field that emerged out of artificial intelligence research. It strives to manipulate information to offer some degree of problem solving ability, and to augment a human's ability to connect both information and concepts in a nonlinear way (Bielawski and Lewand 1991). It uses model expert knowledge in systems that aid in design. It uses this knowledge to provide general design strategies and guidelines as design solutions. This knowledge, as either rules or heuristic, is associated with the design solution as an approximation technique. Generalities associated with this approximation methodologies prevent design aid for specific design problems and potential optimal design solutions as well as the prediction of exact thermal design locations.

To overcome some of these problems, an investigation of the knowledge representation for building thermal design was conducted to select an adequate strategy in conjunction with a problem solving model. This selection took into consideration several factors. First, the representational adequacy where representation has the ability to represent all knowledge in the proposed domain for solving the problem. Second, acquisition efficiency where the ability to add new information into the knowledge is present. Third, inferential adequacy where the representation possesses the ability to manipulate the representational structure in a way that can incorporate new inferred knowledge from old. Finally, inferential efficiency where it has the ability to add new information to the knowledge structure that will help in finding the solution. Taking all of this into consideration, production rules associated with statistical reasoning representation were selected. This representation through generic rules, allows the creation of multi-knowledge agents that facilitate solving reasoning problems.

2 SIMULATION AND AGENTS

A problem detection model for building thermal problems using multi-knowledge reasoning agents was developed using generic rule representation. The model uses input from a thermal simulation program (malkawi 1994). The simulation program is a transit analysis program that provides hourly heating and cooling load predictions for residential and commercial buildings.

In this model, thermal simulation output is filtered and sent to the agents for processing. Before information is provided to the agents, several conclusions are made about the thermal behavior of the building. These include the month with the highest thermal loads for every zone in the building, the month with the highest load for all the zones combined, the highest element in each month for all the zones (heating, cooling, cooling and heating), the building dominate loads (heating or cooling) and the zone with the highest loads. In addition, specific information about the zones in relation to zone loads is concluded. These include, the dominate load on the zone (heating, cooling or heating and cooling). The element in the building with the highest heating, cooling and heating and cooling yearly thermal load for every zone specified in the building. The element in the building with the highest heating, cooling and heating and cooling monthly thermal load for every zone specified in the building. These conclusions are forwarded to the system's working memory (cache) and stored as facts to be accessed by the agents.

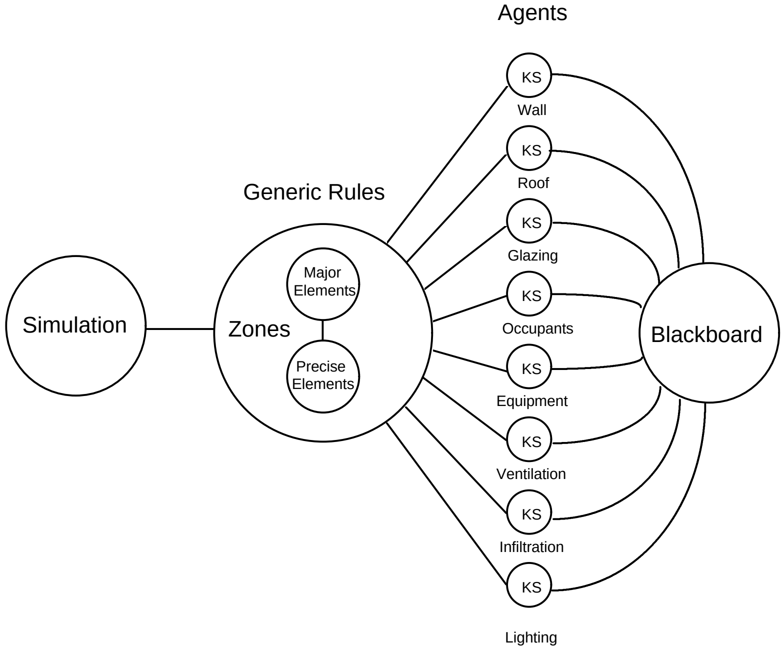
The agents are made up of eight knowledge sources, a blackboard resident in the dynamic portion of the cache, static facts and a controller to perform its reasoning. The eight knowledge sources used are the building elements and systems that affect the thermal behavior of the building. These are: the walls, the glazing, the roofs, the ventilation, the infiltration, the occupancy, the lighting and the equipment. The controller of the agents monitors the blackboard and the knowledge sources. When a problem is given to the system, the controller declares that a solution is being sought by placing the request on the blackboard. The knowledge sources recognize what is on the blackboard and investigate the factual knowledge present about the building's thermal behavior. The first knowledge source that can contribute to solving the problem posts its finding on the blackboard. At this stage, knowledge sources again will observe the problem being solved on the backboard and investigate the thermal simulation output that was forwarded to the cashe and stored as facts. The first knowledge source that can contribute to finding the solution will post its answer. This answer can modify, erase or replace some of the solution segments on the blackboard. This reveals the dynamic nature of the critic reasoning that takes into consideration solving conflicts between different knowledge sources by basically eliminating these conflicts.

The system facilitates exact problem detection in addition to several other functions (malkawi, 1995).   To facilitate this detection, the system determines the building elements and systems and their location that contribute the most to total building thermal problems. This is accomplished by developing two hierarchical levels of problem detection that are strongly dependent upon each other. The first level includes the building zones and the second level includes the building elements and systems that are associated with these zones. The system reasoning process investigates first the zone of the highest possibility of thermal problems and associates this possibility with a degree of belief (cf). It then investigates the elements in this zone that contribute the most to both this zone and the building thermal problems taking into account the zone belief of contribution.

3 AGENT REPRESENTATION AS RULES:

The agents are represented as generic rules which are designed to identify the contribution of loads on the total building performance. These rules are composed of three groups. The first group of rules identifies the worst zone in the building. The second identifies the major element or systems of potential problems and the third identifies the precise elements or systems taking into consideration the previous two groups of rules. Rules access the static facts output from the simulation and activate the virtual agents. These agents are building elements and systems that contribute to the thermal behavior of the building described earlier, figure 1. The findings of the agents are posted on the blackboard. Associated with these findings is a certainty factor that is used in the problem solving modification process.

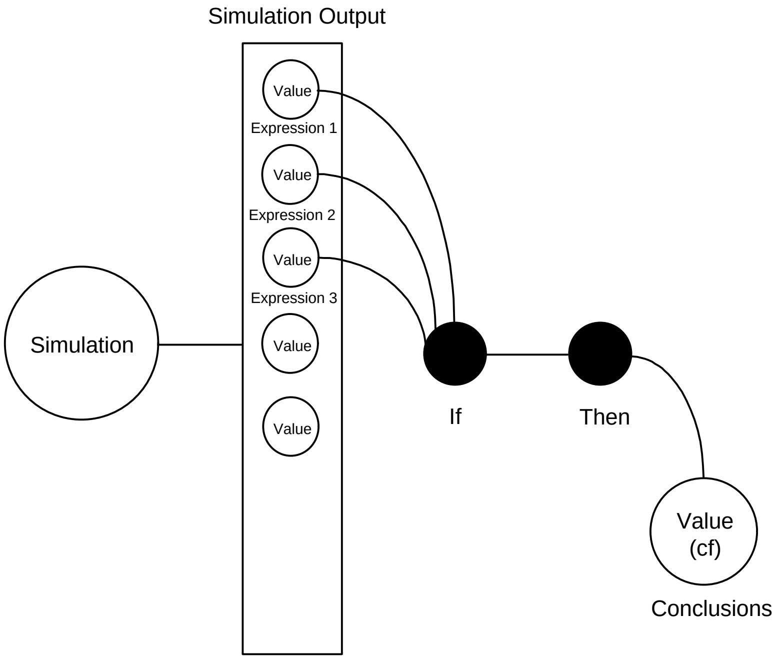
Figure 1: **The Framework of Agents**



The conclusion of the simulation is the knowledge base that the rules will use to determine which agent will be activated. This knowledge base is simply stating values for the output of the simulation and information about the building and its operation which are different for different designs. A segment of this knowledge base entry would be expressed in the form of: *expression* = *value* **cf** *integer.* If the certainty factor (cf) is not present, it will be assumed as 100. For example a knowledge base such as:

ventilation-rate-in-zone- 5 = 15.
ventilation-status-in-zone- 5 = continuous.
Would assume that the ventilation rate in zone number 5 is 15 and its status is continuous both with a certainty of 100. These conclusions will be forwarded to the rules as their premise, figure 2.

Figure 2: **Rule Representation as it Relates to the Simulation Output**



Rules that represent agents are represented in the form of:

if *premise*
then *conclusion*

where premise is a proposition of the form: *expression* = *value* or a combination of such propositions jointed by the Boolean connectives **and**, **or**, or **not**. Conclusions of the rules are made up of propositions also of the form: *expression* = *value* **cf** *integer*. A conclusion of a rule can be a premise of another rule. This allows the rules to take into consideration the effects of uncertainties based on evidence.

A rule is considered relevant when its conclusion can provide a value for the expression currently being sought. For example, if the system is seeking the value for the first problem in the worst building zone: *precise-problem1-max-zone* then the rule:

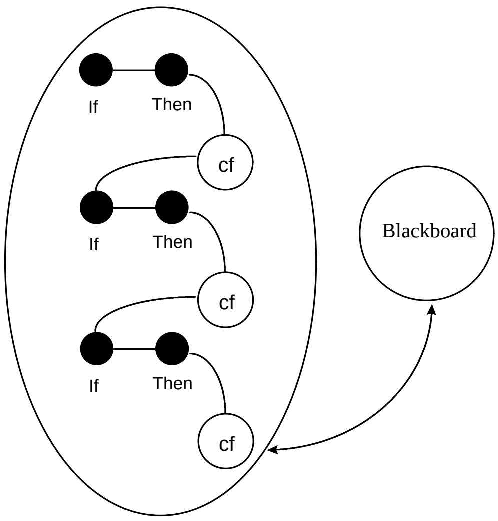
if the-building-dominate-load = X and
problem-zone = MAXZONE and
zone-MAXZONE-no-1-worst-element-X = ZWORST1 and
zone-MAXZONE-no-1-worst-element-X-worst-month = ZWORST1 and
problem1 = ZWORST1
then precise-problem1-max-zone = ZWORST1 cf 100.

will be a relevant rule. But the rule:

if the-building-dominate-load = X and
problem-zone = MAXZONE and
zone-MAXZONE-no-2-worst-element-X = ZWORST2 and
zone-MAXZONE-no-1-worst-element-X-worst-month = ZWORST2 and
problem1 = ZWORST2
then precise-problem2-max-zone = ZWORST2 cf 100.

would not be considered relevant because *precise-problem1-max-zone* is not in the conclusion. Each time a relevant rule is encountered while an expression is being sought, the premise of the rule is tested. This is called invoking the rule. If the premise of the rule is found to be true, the rule is said to succeed and the values within the conclusion are noted with the appropriate certainty factors, figure 3. If the premise of the rule is found not to be true, the rule is said to fail and no conclusion is noted.

Figure 3: **Rules Interaction with the Blackboard**



Variables in the rules act as symbolic placeholders. Each rule that contains variables is logically equivalent to the infinite set of rules that could be obtained if the variables were replaced in all possible ways by terms. Variables in rules are not used as labels, nor is there any assignment statement that modifies the contents of a named memory location. When a variable is instantiated to a particular term, the term is not stored "in" the variable as the variable's "value" rather all the occurrences of the variable are replaced by the term. The variable itself is erased, as it was merely a placeholder for the term. Unlike conventional variables, expressions can have more than one value at a time, and their values are not ordinarily modified once they have been concluded during a consultation. The inference engine seeks values for expressions not variables.

When the engine instantiates a variable in a knowledge base entry, the substitution takes place only within the current "working copy" of the entry. This means that the original rule remains unaltered in the knowledge base and can be reused later with different instantiations. It also means that the instantiation does not affect any other entries in the knowledge base that happen to contain the same variable.

4 SUMMARY

The paper illustrates how generic rule representation can be utilized in building interactive virtual agents. It presented a specific model for utilizing rules in building these agents through combining rule variables with the output of the simulation and the blackboard. This paper showed the ability to manipulate the representational structure of a rule based system in a way that can incorporate collaborative problem solving models such as the blackboard. Through generic rule representation, virtual agents were able to provide problem identification without the use of rules of thumb.

5 REFERENCE

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