Abstract

Knowledge-Based Systems are intelligent systems, which perform intelligent reasoning. However reasoning in this kind of system is very time consuming when there are large amounts of facts, rules or knowledge in the knowledge base. Since most real world domains consist of large amounts of knowledge, this issue has been a common problem. Nevertheless, human experts are still good at dealing with huge amounts of knowledge related to different domains. We argue that this capability is due to experts' ability to classify the rules and apply them for answering without exploring all the knowledge they have. It is evident there is no hard and fast rule for classifying or refining the knowledge but they use a lot of heuristics naturally for this process. Stated in another way, human beings are capable of the use of heuristically classified knowledge for reasoning. However, this aspect has not been exploited sufficiently for improving effective reasoning in knowledge-based systems.

This thesis presents an approach to heuristically classify a knowledge base into sub modules thereby improving the efficiency of reasoning in knowledge-based systems. Hence our philosophy in the approach is the fact that experts are aware of the nature of knowledge in their domains.

This approach enables an inference engine of a knowledge-based system to interact through a heuristically classified module of rules, thereby avoiding exploring a large knowledge base during all the time of reasoning. In general, the

inference engine always looks through the heuristically classified models of rules. If the heuristically classified modules have appropriate rules, then, the rules in this particular module will be fired and give the answer. Otherwise the main knowledge base is used to get the appropriate rules fired. According to the heuristics pertaining to the particular domain, such rules will also be added to appropriate modules. With this approach the modules of rules, which are classified by heuristics will evolve as time goes by. It should also be noted that a particular rule might change the module where it is kept from time to time. So, contents of modules are dynamic.

In designing this heuristics based module, we have identified a set of common heuristics and constructed a model using these heuristics. For example, the model is developed to assists the heuristic classification of rules into three sub modules called *most commonly used rules, uncommonly used rules* and *conflicting rules*. There is a rule analyzer, which works inside the heuristics-based module. The rule analyzer keeps track of usage of rules along with frequency and nature of firing of rules. In this process of classification of rules, the heuristics-based model uses percentage values for rules firing. Total count of each rule fired, total number of cycles the system executed, the last date of any rule fired, are some of the measures done by the rule analyzer. When the percentage relevant to a particular rule exceeds the threshold value, relevant rules will be combined with the heuristics-based module. It should be noted that our key point in the thesis is not the number of heuristics used in the model, but a mechanism to use heuristics

for classification of rules. Further, since different domain experts have different heuristics, it is also counter productive to maintain a universal set of heuristics. Instead, we enable the use of heuristics classification of rules in knowledge-based systems. As we describe later, it has been shown that even using a simple set of heuristics, we can achieve remarkable improvements in efficiency and accuracy in reasoning.

While the heuristic classification of knowledge base is the main contribution of this thesis presents to the field of knowledge-based system, we have also incorporated standard features of knowledge-based systems. In particular the system is capable of handling incomplete information and giving reasons for answers provided by the system. Therefore, the research work presented in this thesis has clearly extended the features of knowledge-based systems, in general.

We have developed the approach as a general module that can be coupled with any knowledge based system. The heuristics-based rule analyzer module can be combined with any standard expert system shell that can be worked on any given knowledge base. The system has been developed using LPA/Prolog - FLEX, which is an expert system shell and works on Windows platform.

We have practically tested the efficiency and accuracy of using the heuristically generated modules for reasoning in knowledge based systems. In doing so, we selected a relatively complicated domain of The Open University of Sri Lanka

(OUSL). This domain is sufficiently large to test the approach given in the thesis. The OUSL students' knowledge base, and the criteria of awarding degrees for the bachelor of education programme has been considered as the testing domain. The experiment has been set up to measure the reasoning time taken by heuristically modularized system and the time taken by the ordinary knowledge base, which is relatively large. Several experiments were carried out while keeping different number of rules in the main knowledge base. Analysis of experimental data shows that on average the modularized system works thirty percent more efficiently than the ordinary knowledge-based system with all rules in the knowledge base. It was also very clearly shown that the percentage goes up when the size of the knowledge base increases. Further, efficacy has been increased as time goes by. Therefore, we conclude that knowledge based systems with heuristically classified modules of rules can improve the efficiency and accuracy of reasoning, in particular in the long run, in large domains.

In essence, this approach has several advantages for the knowledge-based system development community. Among others, firstly, our approach gives a realistic feedback for maintaining large knowledge bases, by indicating how the rules in the knowledge base are to be treated, depending on the nature of knowledge. Secondly, this approach gives a clear idea about how to structure large knowledge bases, by looking at different modules required for effective reasoning. This is an extremely useful result as most knowledge bases are currently structured in an ad-hoc manner.