An Enhanced Natural Language Interface for Engineering Expert Systems

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Abstract

This work describes an enhanced natural language interface for a generic engineering expert system development environment. The engineering expert system development environment is designed to undergo a training period where the system learns to recognize and classify different types of engineering problems based on the natural language problem description. Upon completion of the training period, the system should be able to recognize and classify any type of engineering problem within its training domain based simply upon the natural language description of the problem. The training algorithm is a specialized application of Quinlan's ID-3 algorithm. Once the problem has been classified, the system matches the problem classification to a function template for that type of problem. The function template describes the expected inputs, algorithms, and outputs for each type of problem. The system then goes back to the natural language description of the problem and searches the text for the appropriate inputs, feeds these inputs to the solution algorithm, and returns the result to the user. In this paper, domain specific expert system is described and the two different uses of the ID-3 algorithm to classify the numerous problems are compared.

Introduction

With many applications in the field of education, domain specific computer programs are particularly well suited for implementation in engineering problem solving [2]. Formally, an expert system is defined as a knowledge-based computer program that exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert [3]. This problem method uses a knowledge base, which is carefully formulated on the basis of expert judgment, intuition, and experience. Thus an expert system embodies the cognition and ability of an expert in a certain realm, thus emulating the decision-making ability of a human [8]. The present engineering expert system is well suited to solve problems involving some of the conceptual mechanical engineering aspects and has a knowledge rich domain where effective knowledge control exists to create efficient solutions. The goal of the research described in this paper is to explore strategies that enable an expert system coupled with the training algorithm to yield best possible solutions in a specific domain. In this paper we present two different functional phases of classifying the numerous training problems in the knowledge base by importing the decision making ID-3 algorithm, thus implementing machine learning techniques to improve and organize the acquired data.

Function-based Engineering Expert System

An adaptive function-based expert system is built in an engineering problem-solving environment that serves as a platform that combines qualitative, quantitative and reasoning skills to produce annotated solutions to engineering problems [1]. A knowledge based system is taught in a much similar way as one would teach an engineering student, by furnishing specific examples of problems and solutions, explanations of these solutions, or supervising the system as it solves new problems. To start with, a large set of engineering problems is collected. This set of problems is called the training set. Such training collection is necessary for a non – expert like a program which may need significant tutoring and exposure to reach an expert decision making capacity.

This form of knowledge is acquired by accumulated engineering judgment over the years. The present system has a user-friendly interface and is built on this knowledge coded in a form that allows a computer to solve problems.

Method

Knowledge based expert systems have the combined advantages of sophistication and user friendliness, leading to their extensive application in all facets of engineering. The building blocks of an expert system can be considered as these parts

- Knowledge Base
- Knowledge Acquisition Tool or The User interface
- Inference Engine

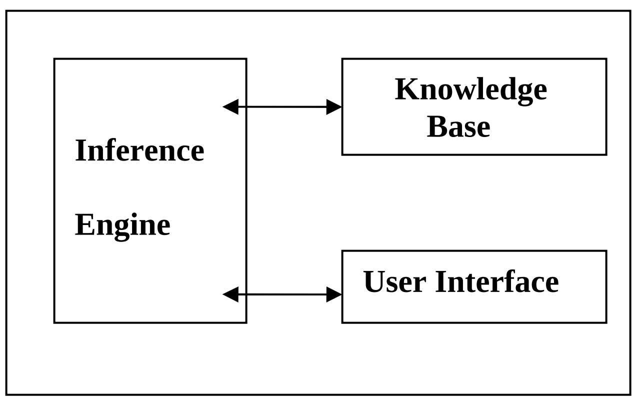

Figure 1: Schematic Diagram of an expert system

This system consists of a problem-solving module for the actual utilization of this application, a training problem acquisition module serves as the knowledge acquisition tool, a decision tree knowledge base, an ID-3 module used to train the knowledge base and build a decision tree, and a function template module for providing the actual procedure for problem solving.

The first major component is the Knowledge Acquisition Tool. The data collected by the user can be easily added to the knowledge base through the knowledge acquisition tool designed to add and modify knowledge with ease [7]. The domain knowledge contains two types of knowledge. One is the large number of engineering problems for the decision-tree training, the other being a set of problem-specific equations for the expert system to use. Both types of knowledge are accepted in textual format and the necessary information will be extracted from the text using natural language processing techniques.

The other two major components of the system are a knowledge base and an inference engine, which is operated as required. The two types of knowledge described above will be stored in a decision tree and in function-based templates, respectively. An inference engine will operate on the decision tree to classify the problem type, and then the corresponding function template will be called to solve the problem. The templates are designed in such a format that they can be applied for any problem-solving situation, so that it will not be necessary to modify the source code to solve a problem from a different domain.

The decision tree will be trained using a training set containing one hundred engineering problems. To test the system, sixty engineering problems not contained in the training set will be solved and compared to solutions obtained by hand.

Expert System Architecture

A data flow for the proposed expert system tool is illustrated in Figure 2. The knowledge experts enter their knowledge through the acquisition module and end users communicate with the machine through the problem-solving module. The various modules and their function can be described in several sections.

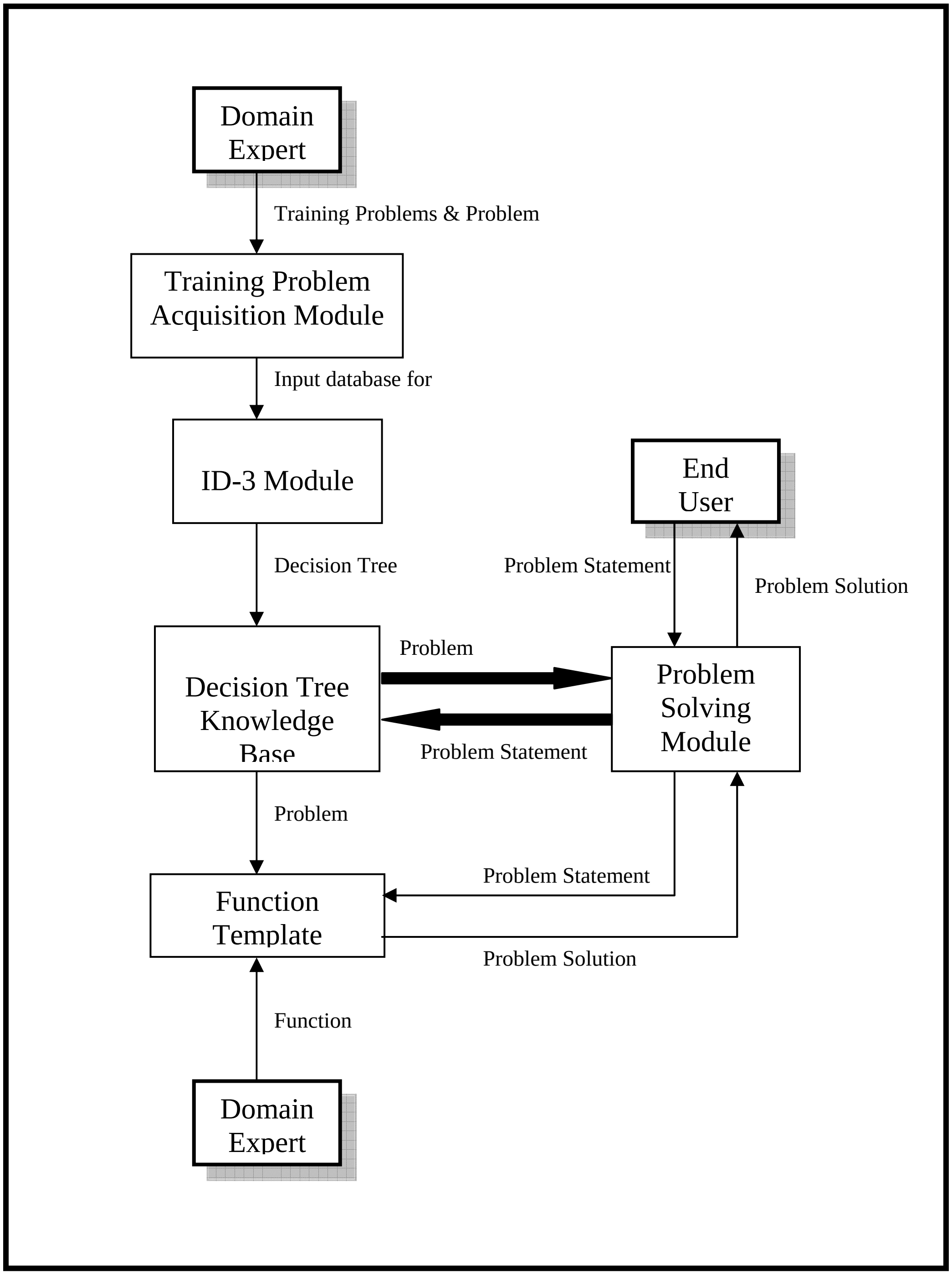

Figure 2 – Data-Flow for Proposed Expert System Tool

1.1 Knowledge Base:

The knowledge base comprises the integrated knowledge system built on the basis of knowledge of an expert. It holds the complete set of information that may be needed within a specific problem area. Here a modular knowledge base is proposed which is separated from the inference engine, thus enhancing the flexibility of representing the expert information [6]. This application is built on numerous engineering problems secured from a standard engineering textbook. The problem areas deal with various sections of mechanical engineering like static's, dynamics, energy, thermodynamics and vibrations. The executable knowledge base is created and stored in a text editor or a word processor and the format required by the program code is followed. The modular knowledge base is carefully formulated by imparting expert domain knowledge and is complete and reliable as closely as possible [9]. All the problem statements are phrased in natural human language avoiding redundancy to improve efficiency and facilitate easy maintenance. Typically the system has about a hundred problems. During interactions the knowledge base of the system is extended and corrected until the satisfied performance is achieved [4]. The knowledge development process comes to a stop when the system has been trained with examples of the main classes of problems it is expected to solve. Thus allowing the system to solve most of the problems in a domain of expertise.

1.2 Knowledge Acquisition Tool

A knowledge acquisition tool has been developed that allows an expert or a knowledge engineer to conveniently provide the knowledge and data [10]. Since the systems rely heavily on expert knowledge, the quality of knowledge acquired will often be the determining factor in its success and the performance [9]. The tool stores all the information into the knowledge base in standard format that the inference engine can use to solve problems. The set of training problems for the decision tree are gathered and saved in an apt format for further retrieval.

1.3 Problem Solver Interface (Inference Engine)

The inference engine of the expert system is shown in Figure 3. Also known, as the Problem Solver Interface is the final module, which directly interacts with the end user. An engineering problem in text form is entered in the text box provided for problem entry, then the user goes for the classify command button provided. The problem type will be displayed in the second text box. The problem classification is performed by the decision tree-based expert system. Next, the user opts for the Solve and Display button. At this point, the function template corresponding to that problem type is accessed. The function template uses Natural Language Processing (NLP) to parse the textual problem description for the appropriate variable-value pairs. Given the proper variable input values, the function template solves the problem and reports the solution to the user in the lower text box of the form, as shown in Figure 3.

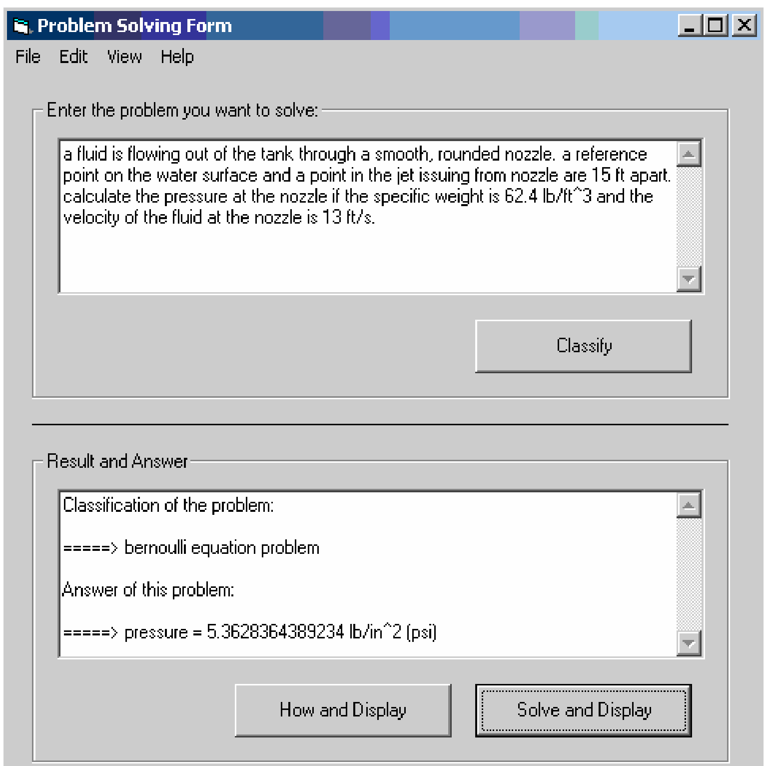

Figure 3 – A Problem-Solver Interface

Application of ID-3 Algorithm

The proposed expert system has been implemented using the ID-3 algorithm using the Visual Basic programming environment. The rich knowledge base undergoes a training period where it learns, adapts and is classified in to various engineering problems [5]. The problem statements provided in the natural language are formatted in a way where the system can understand and classify accordingly within the training domain [11]. The training algorithm operates on the specific data from the formatted files. Here the training algorithm is a specialized application of an Iterative Dichotomizer (ID-3) algorithm. Presently this algorithm is applied in two different ways. One way is by incorporating the whole problem statement in which each word forms an attribute contributing to the decision making process executed by the classification algorithm. Secondly the algorithm is made to work on a particular set of words held in a function template that has the problem solving procedure and the required inputs to obtain a solution. Implementing the ID-3 algorithm on two different modes of knowledge, though both imported from a similar textual format is expected to give different classifications. A sample decision tree for a few engineering problems is illustrated in the decision tree diagram shown below (figure 4)

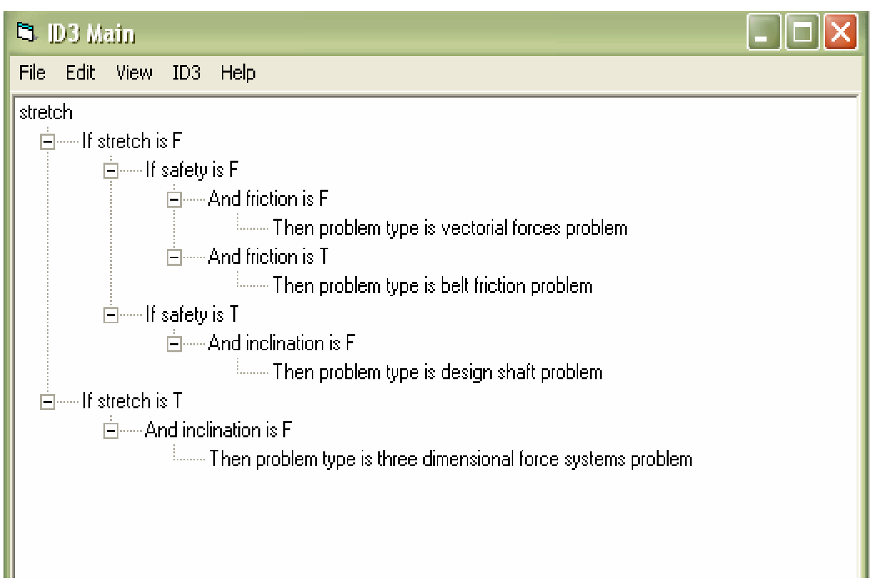

Figure 4 – Decision-Based Tree Diagram

Conclusion

The present expert system can be enhanced further for more accurate decision trees and problem solutions. The performance of the expert system depends heavily on the completeness of the knowledge base. Better problem classification is presented from a rich knowledge base. Thus a more reliable and complete domain knowledge is proposed for future domain specific problem solutions. Also the process of knowledge acquisition can be automated for fast and simplified knowledge gathering.

As the dependence on the knowledge base created by the ID-3 is more, it is recommended that ID-3 algorithm be modified and upgraded in the future. Another task would be enhancing the search capability of the input values by providing alternative keywords for the general variables provided in the problem description. Further sophisticated ways of knowledge representation, acquisition and integration are suggested for a technologically advanced system.

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