FORTH, EXPERT SYSTEMS, AND MECHANICAL ENGINEERING EDUCATION

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Abstract

As a result of research in the field of Artificial Intelligence, the technology of expert systems has emerged as a popular programming methodology. The use of Forth as a development language for expert systems has been motivated primarily by the need for intelligent real-time control. However, Forth can also be a very powerful tool for expert systems that do not operate in real-time, i.e., consultant systems. We have developed both knowledge-based consultant systems and intelligent real-time monitoring systems using EXPERT-2 and Forth. This paper presents some of the advantages offered by knowledge-based systems in Forth, and describes how these systems have been used as educational tools to train mechanical engineering students.

Introduction

Knowledge-based (expert) systems can be expected to play an increasing role in the working life of a professional engineer. In the Mechanical Engineering department at the University of Saskatchewan, we have been using EXPERT-2 [1], various implementations of Forth, and a variety of microcomputers to expose the student to this important and rapidly developing branch of technology. This paper describes some of our recent experiences of applying EXPERT-2 to real-time and consultant systems in an undergraduate environment.

Applications

Fault-diagnosis in Strain-gauge Laboratory

One of the laboratories in Mechanical Engineering involves the placing of strain-gauges on a steel specimen followed by an experimental stress analysis using this strain gauge configuration. During placing of strain gauges, several faults may occur, for example, dry joints, shorts, grounding faults, improper specimen preparation, and so on. Such faults are commonly made by inexperienced students. In previous years, considerable supervisory time has been expended in diagnosing these faults. Since the advice was repetitive, the use of an expert system seemed appropriate.

Currently, the lab is provided with a small expert system running EXPERT-2 in Superforth on a Commodore C-64 microcomputer. The expert system provides for a diagnosis of faults in strain gauge application. The use of an expert system for this task is justified by the fact that the domain is small and complete.

Expert Systems in Design Projects

Senior year mechanical engineering students at the University of Saskatchewan are required to participate in a comprehensive design project. This project may be industry or research oriented, and has the same weighting as a two-term core class. On an individual project, students usually work in groups of 2 or 3, and approximately 150 hours of effort per student is involved over the full academic year. Each design team is required to submit a formal engineering report, and to present its work in a 20-minute platform presentation to the whole class and invited guests from industry, government, and other faculties.

During the past few years, several such design projects have involved the design and implementation of an expert system. The aim of these particular projects is to expose students to this developing area of engineering. Two of these projects will be described in this paper. These expert systems have been implemented using EXPERT-2 as modified locally [2]. The main advantages of EXPERT-2 for these projects are:

- The ability to run on microcomputer systems
- Rules written in EXPERT-2 are expressed in plain english clauses, circumventing the need to learn other high-level languages such as Lisp or Prolog
- EXPERT-2 allows access to the underlying Forth if calculation or interfacing to external devices be required
- Cheap!!!

1. Stainless Steels Selection

American Iron and Steel Institute (AISI) classified wrought stainless steels number about 60. These steels fall into 3 groups: martensitic, ferritic, and austenitic. Within each group, there are one or two general purpose alloys which form the base composition for other alloys in the group. Modifications to the compositions of these base alloys are required to meet the demands of specific applications, for example, nuclear, high temperature, welding, and so on. Obviously the correct selection from such a group requires considerable expertise, and thus, lends itself to the use of an expert system.

"Expertise" for this project was obtained from textbooks and handbooks. Considerable effort, however, was necessary to organize the information in a systematic fashion to accomodate the consequent-reasoning process in EXPERT-2. The system functioned at the expert assistant level, and the completed system contained about 200 rules.

2. Condition Monitoring of Hydraulic Circuits

The performance of hydraulic circuits is not constant, but varies with time. Fluid contamination, component wear, and leakage all contribute to a loss of efficiency and reliability. Scheduled maintenance is the traditional method to prevent catastrophic failures. An introspective circuit could perform self-diagnosis to predict incipient failure or to signal performance degradation.

Recently, a group of students took on a design project to study condition monitoring of hydraulic circuits. The three students who participated in this project divided it into three parts:

- building and instrumenting a hydraulic test circuit to simulate reductions in volumetric efficiencies in various hydraulic components
- interfacing the instrumented circuit to the computer
- writing an expert system to continuously monitor the circuit and detect the occurence of a change of state

Each part was performed by an individual student.

EXPERT-2 and Forth have obvious advantages in this project. For example, the student who developed the expert system initially wrote rules such as:

```
IF sensor_1_is_ok
AND sensor_2_is_ok
        .
        .
        .
THENHYP the circuit is performing according to specification
```

This rule-base could be written and debugged independent of circuit hardware.

The student who developed the interface between the computer and the hydraulic circuit could therefore write a Forth word,

```
sensor_1_is_ok
```

which checks that sensor 1 is operative and that the parameter being measured is within an acceptable range. If all is ok, a true flag is pushed onto the stack. If not, a false flag is returned. These words could be thoroughly debugged independent of the expert system. A simple editing of the operators in the rule-base, as shown below, completes the program.

```
IFRUN sensor_1_is_ok
ANDRUN sensor_2_is_ok
        .
        .
        .
THENHYP the circuit is performing according to specification
```

It is doubtful that any other expert system shell or tool-kit currently available would allow this ease of connection.

Expert Systems as Teaching Tools

The stainless steel selector previously mentioned, and a hydraulic circuit design package currently under development as a M.Sc. research project [3] have both been used in undergraduate laboratory exercises. Initially, the aim was to have a large number of independent tests of these expert systems. However, it was quickly realized that exposure to the decision-making process for these applications gave the students a clearer understanding of the underlying principles involved. By forcing students along a decision path, the logical nature of the material selection or design process was made more apparent. The use of expert systems is obviously an effective technique to transmit not only the knowledge itself but also the mechanics of the decision-making process.

Conclusions

Knowledge-based systems are likely to play an increasing role in the engineering profession. Familiarizing students with knowledge-based systems at some point during their education prepares them for the future widespread application of this technology in the engineering field. Only a limited amount of time can be devoted to this area. It is therefore important that the central concepts of knowledge-base construction be presented with as little interference as possible from peripheral irrelevancies. The student should not have to learn Lisp or Prolog in order to write a simple rule-base.

EXPERT-2 allows the writing of rules in near-english form and thus provides an appropriate environment for the tyro. The ability to access the underlying Forth system simplifies the extension of the rule-base for communication with the outside world.

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