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REGAD: An Expert System for Registration Advising*

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At Louisiana Tech University, students meet with an academic advisor each term to discuss progress and plans in their particular curriculum. This paper describes the development and use of an expert system (ES) to assist in the advising process. REGAD was originally developed as an exercise in expert system development and it secondarily exhibited practical utility in the on-going academic program. The system provides the student with a list of the eligible courses required for the Bachelor of Science in biomedical engineering curriculum. The courses are listed in order of priority as determined by the experience modeled in the system. It was used successfully by over 125 students, advised by four faculty members, for four terms.

INTRODUCTION

Goals

IN A highly structured yet interdisciplinary program such as biomedical engineering, advising students about course schedule and registration is time-consuming but necessary. One problem encountered in registering undergraduates through the biomedical engineering curriculum is that the advisor has to remember all the prerequisites to courses in the major. For example, the first biomedical engineering instrumentation course has seven prerequisites before a student is eligible to take the course. Biomedical engineering courses follow various courses taught in other departments, e.g. electrical engineering, engineering mechanics and zoology. It is therefore difficult to remember all rules or exceptions for course eligibility. In addition, it is very important to take courses in the correct sequence because some higher-level courses are taught only once per year. A flowchart was constructed to alleviate the above problem. The flowchart was intended to show the proper sequences of courses a biomedical engineering student must follow to obtain a degree. Unfortunately, the flowchart was very complex and resembled 'spaghetti with square meatballs'. Another means of keeping track of the courses and their prerequisites was therefore needed.

The expert system (ES) we describe here contains the knowledge and rules for consistently advising a student. The computer system gives more time to the advisors to discuss individual course loads and progress in the curriculum considering personal factors. The advisor is usually limited as to the time allocated for a student advisement period due to the number of advisees. In the past the advisor had to find all the eligible courses and suggest the course load for a particular student. Our ES supports the student in his/her responsibility to understand the curriculum and make wise course-scheduling choices.

A second motivation for this project was to facilitate the departmental artificial intelligence interest group in learning/practicing ES development. The narrow knowledge domain (course selection advisement), local expertise (faculty member) and potential value (advisement aid) are key factors of successful ES development. The demonstration problem needed to be non-trivial but not too technical, so that a novice could focus on learning techniques of knowledge engineering and knowledge acquisition.

Expert systems

An ES is a computer program that solves problems in restricted domains using logic and reasoning designed by humans [1]. Ideal ESs reach the same conclusions that a human expert would reach if faced with the same problem. Experts are defined as individuals recognized for problem-solving skills in specific knowledge domains [2]. Building an ES (called knowledge engineering) essentially involves an interactive process between the ES builder (called the knowledge engineer) and a human expert in the narrow knowledge domain area to be computer-simulated [3]. The knowledge engineer extracts strategies and heuristics from the experts. The information contained in our ES,

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REGAD, simulates the advice from faculty for registering a student.

General advantages

Artificial intelligence, or the computer recording of expertise, offers several advantages over human expertise. Artificial expertise is permanent, transparent, consistent and economical. An ES facilitates dissemination of the specialized knowledge in the problem domain. This is the most significant advantage of an ES for the registration advising problem. This point is especially true if the ES is built using a prevalent computing environment. Transparency of the knowledge base is an attractive feature of the ES approach, as this permits easy modification and readability of the knowledge base by both the domain expert (faculty member) and system user (faculty and student). Furthermore, the knowledge required to draw conclusions or make recommendations is formalized and clarified through explicit reasoning, elicited from recognized, and articulate, human experts. Another advantage of ESs is the ability to reason with heuristic or uncertain knowledge. This allows the expert being interviewed to provide knowledge based on experience and rules-of-thumb. The knowledge in REGAD contains assigned certainty ratings for given conclusions.

Meeting the requirements for ES development. Registration Advisor (REGAD) satisfies all of the general requirements for ES development [3]. One of the most important requirements is that expertise exists in the problem area. A single faculty member with 5 years of advising experience and administrative responsibility for the undergraduate program provide the knowledge.

Another requirement is that the task to be performed by the ES (e.g. registration advising) must ordinarily require only the cognitive skills of the professionals. Tasks requiring expert physical or perceptual skills may be inappropriate for ES development. The problem of registration advisement is cognitive in nature. Furthermore, the solution to a problem must be clearly understood and explainable. This problem was chosen because it is well understood (by the contributing faculty members) and therefore convenient for concentrating efforts on the knowledge-engineering aspects, rather than on understanding the problem's concepts.

Appropriate ES problems [4] are heuristic in nature, i.e. rules of thumb are used to obtain acceptable solutions. Problems that can be solved by algorithmic procedures which obtain the exact solution every time are not suitable for ES applications. Curriculum advising requires knowledge of course requirements, published and required prerequisites, and general heuristics about good course sequencing.

Furthermore, the task must be of manageable size. Size may be estimated by the amount of time necessary for a human expert to reach a conclusion after all information has been made available. A problem that would take an expert hours to solve, even with all the data previously obtained, would be too large. A problem that takes 20–30 min would be reasonable to consider for ES technology. During preregistration advising, the faculty member spends approximately 10 minutes with a student.

Specific advantages

An expert system to advise students offers several advantages to the faculty and students. The advisor is freed from the laborious and error-prone task of identifying possible courses for the student. Transparency of the REGAD knowledge base permits easy interpretation of the knowledge base by the faculty advisor. This facilitates system development, evaluation and use. Conventional programming languages may restrict this communication process. REGAD provides an explanation of reasoning strategy to the advisor at the end of a consultation by displaying the rule number that concluded the fact under investigation. This explanation facility increases the advisor's confidence [2] by offering each advisor the opportunity to evaluate the system's recommendations.

Role

REGAD assists biomedical engineering undergraduate students in preparing for their advising appointment. The student consults the system, before meeting with his or her advisor, for all the possible courses the student is eligible to take during the next term. The list is presented in a priority order. The advisor then only has to advise the student on the course load that the student should take from the list of courses recommended by the ES.

Scope

The registration advising ES incorporates knowledge about the complete, 139 semester hour biomedical engineering curriculum and when courses should be taken. At Louisiana Tech University, the terms are based on a quarter calendar with semester credit hours. REGAD suggests a list of courses that the student is eligible to take based on courses passed, student classification and course requirements. The system incorporates the knowledge necessary to guide a student through one of the three technical elective tracks (in chemical, electrical or mechanical engineering) in the biomedical engineering curriculum. (A fourth track has since been created for students planning to enter medical school.) A student and advisor then agree on a specific schedule, considering the individual's grade point average, extracurricular activities and responsibilities, and study skills of the student. This part of advising requires interaction between the advisor and the student and varies with faculty member as well as student. Expertise in this aspect of the advisement process may exist but would not generally be agreed upon. Therefore,

this aspect was not included in REGAD. The system's knowledge prioritizes suggested courses based on the course sequencing considerations, e.g. technical electives and mathematics courses should be taken early. The current curriculum check sheet and other written advisor material continue to be useful to the advisement process and have not been replaced.

METHODOLOGY

Building an expert system may proceed through five stages of development [3, 5]: problem identification, conceptualization (of problem-solving strategies), formalization (of key concepts), implementation (of the formal knowledge via a working computer program) and testing (of the performance of the prototype program).

Problem identification

This first stage involves identifying the problem characteristics and resources [5]. The substantial problem of advising students prior to academic registration is an appropriate domain for ES development, as described above. As a preregistration consultant, the ES should incorporate the knowledge necessary to advise a student on the courses he or she is eligible to take. The system should provide the student with a print-out of the eligible courses to take to his or her advisement appointment.

Conceptualization

During conceptualization, explicit relationships are established to relate the key concepts. Information on required courses, elective courses, prerequisites and tentative course offerings is published in the Louisiana Tech University Bulletin (Catalog) and summarized on curriculum checksheets and listings of non-technical and technical electives, which are given to every student. Additional knowledge on the importance of courses and suggested prerequisites was provided by one faculty member (the Department Coordinator of Instructional Programs). The courses were grouped into 10 categories: biomedical engineering, electrical engineering, mechanical engineering, chemical engineering, mathematics, physics, non-technical electives (required and optional), zoology and chemistry. Other significant concepts include student's classification (based on semester hours), technical elective specialization and term.

Formalization

Formalization involves structuring the key concepts and information flow characteristics identified during conceptualization [5]. The knowledge is now formulated in a fashion that can be used in the knowledge base of an ES development tool. The knowledge of this problem area is conveniently represented in if–then rules. The premises of the rules represent course prerequisites; student characteristics and the conclusions represent suggested courses.

Implementation

The decision-making task of course selection may be seen as a backward chaining inference strategy, backing through appropriate rules from the goal-state. The system goals are driven to find the eligible courses for the student. The course selection process simulated here may be described as a structured selection problem; this class of problems has been shown to accommodate backward-chaining inference. A symbolic ES programming tool, or 'shell', M.1 by Cimflex Teknowledge, was selected for implementing the rule-based, backward-chaining system. M.1 is a PC-based development tool with the required types of inference and knowledge representation. It has a convenient user interface with ample documentation. Furthermore, M.1 provides a reasonable uncertainty handling mechanism and debugging facilities.

Testing

The system was tested by using student records and determining if the system's advice was consistent and complete. All biomedical engineering students were required to consult REGAD before their advising appointment each term beginning Fall 1988 (for advising prior to Winter 1988–89). Approximately 125 students per term used the system. Faculty members used the print-outs and provided evaluation and feedback on the overall performance of the system, specific REGAD conclusions and user interface considerations.

RESULTS

The knowledge base of REGAD required 50 kbyte of disk storage and contained 161 rules, 8 facts and 95 meta-facts (control knowledge). System development required approximately 200 person hours of knowledge acquisition, programming and testing. A consultation with REGAD requires approximately 3–5 min. The knowledge base contains if–then rules and explanation meta-facts. A typical if–then rule is shown below.

```
if the term = fall
and had biomedical engineering 100 = yes
and had mathematics 230 = yes
and had chemistry 102 = yes
and had zoology 111 = yes
and had zoology 112 = yes
then course = biomedical engineering 201.
```

The inference engine uses backward chaining to determine if the student is eligible for the course, biomedical engineering 201 (BME 201). The student's background (courses completed, classification, term and specialization) must satisfy all premises of the rule before the conclusion can be made about the BME 201 course. For this course,

students must take BME 100, Math 230 (calculus), Chemistry 102 (inorganic chemistry) and Zoology 111 and 112. One advantage of an ES's knowledge base is the flexibility/modifiability of the records. If the course has been changed from the Spring term to the Fall term, the knowledge base has to be changed by updating the rule for this particular course.

Another example of a rule used by REGAD to find the appropriate course with the use of certainty factors is shown below.

```
if classification = freshman
then course = speech 377 cf 50.
```

Speech 377 (public speaking) is assigned a certainty factor of only 50 for freshmen, higher for higher classifications.

REGAD can be consulted in two different modes: as a first-time user or as a previous user. During the first-time consultation, the system queries the student on the following: student's name, identification number, academic classification, term and all courses previously completed with passing grades. This information is stored in a file coded by the student's ID number. The previous-user mode queries the student only for the term, academic classification and the courses passed during the last term. REGAD prints out a hard copy of the recommended courses for the coming term and the courses that the student has passed, as shown in the appendix. The courses are ranked in the order of importance to complete, e.g. math courses must be taken early in order for the engineering courses to be taken. The co-requisite for any recommended course will also be listed. The courses with the highest certainty factors should be taken as soon as possible so that the student will not be delayed in receiving a degree.

Evaluation of the ES was provided by comments made by the faculty members and student users. The faculty wanted the system to be used/required for every term advisement period. The faculty members were excited about the ease of advising their students after using REGAD. The time required to advise the student on specific courses was reduced significantly. The print-out was tailored for clarity and content based on suggestions from the faculty members. The students are generally in favor of the system, but some show resistance about the extra time (not more than 10 minutes) or responsibility required from them.

DISCUSSION

A number of computer programs have been developed to aid in the registration process. The University of Texas at Arlington developed the College of Engineering Students Advisor (CESAR) [6]. CESAR's role and scope are similar to REGAD's. CESAR interacts with the campus computer and student records; this could be seen as a disadvantage. The evaluation showed such consistency in advising that the project prompted a campus-wide system for student advisement. At the Texas Christian University, a Course Advisor (CSAD) is a prototype rule-based ES [7]. The system's users are faculty advisor and students who are undecided about their degree major. The system produces student profiles for each major based on the performance of outstanding students in the discipline. The profile is based on course work taken in classes outside the major area of study. The system's knowledge was acquired from the school's catalog, which can be easily translated into rules for the expert system. The scope of CSAD is different from REGAD because the students using the former have not previously determined their major [7]. At the University of Arkansas, another expert system, Mentor-I, is an intelligent database to guide students through the curriculum. The advisor is the primary user of this system. The knowledge in this system pertains to the University of Arkansas advising process and course planning [8].

REGAD met all of the initial goals set for a registration advisor. The system was used quarterly to aid the students in progressing through the Bachelor of Science curriculum in biomedical engineering.

The project allowed the AI group to solve the problem via ES development. This is a good exercise for learning about ES development because all aspects of knowledge engineering were encountered and practical value was exhibited. The problem was not very complex in nature. The exercise could be beneficial to AI groups within other departments of engineering. Although expanding REGAD to meet college-wide needs would not be difficult, the development process could be helpful to individual departments.

In some ways, REGAD was too successful. During the evaluations the faculty enthusiastically provided suggestions for additions to the system, such as including class scheduling information and automatic updating of academic progress. However, these items were beyond the scope of the original goals and of the developer's interests. Some of the published systems with similar goals include more of these aspects of registration advising.

SUMMARY

The problem was to find a practical solution to enhance the advisement process by simulating some of the responsibility of a faculty advisor. REGAD solved the problem via a pre-advisement consultant system to find eligible courses for the student user. It also helped the developers to gain specific experience in ES development. REGAD demonstrated practical value as part of the advisement process in the Department of Biomedical Engineering at Louisiana Tech University.

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APPENDIX

```
Student Name = john_doe
Date = 2-6-1990
Quarter for this Registration = fall
Student's Specialization = electrical_engineering
Student's Classification = sophomore

      Regad has determined the list of classes which you are eligible to take
next quarter.  The list is ordered by priority (#%).  Select primarily from
the courses with the highest priority.  Your advisor can help you decide the
specific courses, considering personal, individualistic factors.

*********************************************************
* REGAD has determined that the students should select *
* from among the following courses.                     *
*********************************************************

    course = math 232 (100%) because rule-28.
    course = biomedical engineering 205 (100%) because rule-32.5.
    course = physics 202 (100%) because rule-45.
    course = zoology 202 (100%) because rule-55.
    course = history elective (100%) because rule-67 and rule-64.
    course = social science 1 (100%) because rule-68 and rule-64.
    course = english 102 (100%) because rule-75.
    course = engineering mechanics 201 (100%) because rule-89.
    course = electrical engineering 229 (100%) because rule-115.
    course = electrical engineering 331 (100%) because rule-117.
    course = industrial engineering 400 (80%) because rule-95.
    course = chemistry 250 (60%) because rule-50.
    course = speech 377 (60%) because rule-83.

*********************************************************
* REGAD has the following courses on file as having been *
* successfully completed with passing credit.           *
*********************************************************
biomedical engineering courses completed
      biomedical engineering 100
      biomedical engineering 201

chemistry courses completed
      chemistry 100
      chemistry 101
      chemistry 102
      chemistry 103
      chemistry 104

engineering courses completed
      engineering 102
      engineering 151
      electrical engineering 226

mathematics courses completed
      math 230
      math 231
      math 111
      math 112

nontech_electives courses completed
      art

physics courses completed
```

```
      physics 201

required_nontechnical courses completed
      english 101
      economics 215

industrial_engineering courses completed
      none

zoology courses completed
      zoology 111
      zoology 112

electrical_engineering courses completed
      electrical engineering 221
      electrical engineering 222
```

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