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GOVERNMENT/ACADEMIA COLLABORATION IN
EXPERT SYSTEM PROTOTYPE DEVELOPMENT FOR
NASA APPLICATIONS

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ABSTRACT

Artificial intelligence (AI) technology, and in particular expert systems, has shown potential applicability in many areas of operation at the Kennedy Space Center (KSC). In an era of limited resources, the early identification of good expert system applications, and their segregation from inappropriate ones can result in a more efficient use of available NASA resources. On the other hand, the education of students in a highly technical area such as AI requires an extensive hands-on effort. The nature of expert systems is such that proper sample applications for the educational process are difficult to find.

This paper describes a pilot project between NASA-KSC and the University of Central Florida which was designed to simultaneously address the needs of both institutions at a minimum of cost.

The project, referred to as "Expert Systems Prototype Training Project" (ESPTP), provided NASA with relatively inexpensive development of initial prototype versions of certain applications. University students likewise benefit by having expertise on a non-trivial problem accessible to them at no cost. Such expertise is indispensable in a hands-on training approach to developing expert systems.

1.0 INTRODUCTION

NASA-KSC realized the potential of expert systems technology in late 1983, when it authorized the development of an expert system to diagnose the delicate and potentially disastrous liquid oxygen (LOX) loading process. This process has been monitored through a number of conventional process control alarm and monitoring programs, which are supplemented by twenty highly trained engineers [1]. The LOX loading system is so complex that a human can no longer consider all the possible causes, generate a diagnosis, and arrive at a correct recovery plan in the few seconds allowed.

The resulting work, called the LOX Expert System (LES), was developed by NASA-KSC engineers in cooperation with the MITRE Corporation. LES is a frame-based shell which captures the expertise of an engineer trained in general trouble shooting. The knowledge base, represented as frames, is then added to reflect the actual system being diagnosed. LES also uses a sophisticated graphic process to display the system being monitored.

Other AI development projects followed at NASA-KSC. The list is too long to mention in its entirety, but other notable systems to emerge are KATE, EMPRESS, and the "Thunderstorm and Weather Forecasting Expert System" (TWFS).

But this only served to whet the appetite of NASA's technical management. Recently, there has been a realization that there are a large number of smaller potential applications, suitable for PC-based shells. The abundance of such applications, each of which must be carefully analyzed for its true applicability, have led NASA-KSC to look for alternative ways of performing such an evaluation.

Clearly, the best way to determine the true applicability of a potential problem is to develop an initial prototype. This, of course, requires the involvement of a trained knowledge engineer and an expert. While access to latter may represent no significant problem at KSC, the former, however, are in short supply everywhere. One alternative investigated was to bring them from commercial service organizations, usually at a considerable cost.

The University of Central Florida Computer Engineering Department had taught a master's level hands-on course on the knowledge engineering aspects of expert systems development for the last two years. One obstacle for some students, especially full-time students not employed in their profession, was their lack of access to a real-life problem with outside expertise available for consultation. A similar situation existed at the College of Business Administration where a course similar in nature to the one described above (but with slant towards business applications) was instituted in the Fall of 1987.

The ESPTP solves both problems by providing students enrolled in these classes identification of an application and access to the experts at KSC

to develop the prototype required as a term project in the class. The benefit to NASA, of course, is that a prototype is developed by the students under the supervision of the course instructor. The final documentation as well as the prototype itself are submitted to NASA-KSC for their own use as part of the agreement. This provides NASA-KSC with good evidence on which to decide whether continuation of the project is warranted or not.

2.0 IMPLEMENTATIONS OF ESPTP

As part of the agreement, NASA-KSC provided a \$31,025.00 grant to UCF to cover hardware and software purchases for educational purposes. The software acquired included a site license with one year maintenance for the Texas Instruments "Personal Consultant Plus" (PC+) expert system shell. PC+ is a popular micro-computer based shell written in PC Scheme. A close relative of EMYCIN, this shell was chosen because of its relative simplicity and good support as well as its similarity to EMYCIN. Additionally, it is already being used for other projects at KSC. The site license purchased also included "Personal Consultant Easy" (PCE) and "PC Scheme," an object-oriented version of LISP. Ashton-Tate's "dBase III Plus" and "Dr. Halo" graphics package by Media Cybernetics were also obtained under the grant.

Computer hardware purchased with the grant funding consisted of several IBM-compatible computers, Kodak Datashows and overhead projectors, located on carts for ease in transporting to the classroom.

2.1 Application Identification

NASA-KSC assisted in the identification and pre-selection of the projects to be explored. This was necessary due to the importance to NASA of the project applications. Additionally due to the relatively short duration of a semester (15 weeks), the participation of the students in the project identification would have been unrealistic. The criteria used for selection of applications were:

- useful
- feasible
- educational (when appropriate)
- heuristic in nature
- non-trivial

Five projects were identified by NASA for the business course and two for the engineering course. These were as follows:

Business:

- 1) Launch Vehicle Processing Simulation Assistant
- 2) Automated Data Processing Equipment Acquisition Plan Advisor
- 3) NASA Retirement Expert System
- 4) Customer Requirements Identification Expert System
- 5) Financial Accrual Data Expert System.

Engineering:

- 1) LOX and GOX Ignition Source Expert System
- 2) Hazardous Gas Expert System

2.2 Application Development

It was intended that student teams in each course would develop prototype expert systems which would address the feasibility of the application. Due to the one-semester duration of the course, demonstration of depth and breadth in the resulting prototype would be encouraged but not required. It was then envisioned that those applications which indicated promise would receive additional funding by NASA-KSC to be further developed by NASA personnel.

The requirements placed upon the students in terms of general scope were basically similar for the business and engineering courses. There were, however, some differences in how the project teams were chosen and structured, as well as the more detailed scope requirements. For this reason, a further description of the ESPTP will be broken down into Business and Engineering.

2.2.1 Business Projects

Students in the business class were divided into five teams of three to four members each. This accounted for all of the students in the class. A course requirement was that all students participate in the NASA applications. In order to simulate as much as possible a real world corporate environment, each team consisted of a Project Manager, one or two Knowledge Engineers and one or two Shell Specialists. However, each student was required to become familiar with all aspects of small-scale expert system project development. The project responsibilities (titles) were selected by the students themselves.

A minimum of fifty rules would be required for each application. However, the teams were encouraged to identify as many rules as were feasible and appropriate in the time available.

The teams were required to meet with the NASA experts no less than three times during the course of the project. These had to be completed before the mid-term point (8 weeks).

Documentation required was a typewritten project report which included copies of the knowledge base. These reports consisted of two parts:

- executive summary (3 to 5 pages)
- project report (including the executive summary)

Each team was required to make a project presentation and software demonstration of their work to the class prior to the end of the semester (45 minutes to one hour in duration). The NASA sponsor and experts were invited to the presentation. A copy of the project report and a diskette containing the knowledge base were submitted to NASA.

2.2.2 Engineering Projects

Since two NASA application projects were not enough to go around for a class of 33, participation in the NASA project was not a course requirement. The students were asked to come up with their own applications and form their own teams. A sign-up sheet was prepared for those students interested in working on a NASA application. The course instructor selected the students who were to participate in the NASA application, based partially on their chances for success. As such, two teams of two students each were chosen to work on the NASA projects.

A requirement placed on the general class was that teams be no larger than three members. Two person teams were encouraged as the ideal, but single person "teams" were allowed as well. The selected NASA teams, however, had to have at least two and not more than three members in an effort to "share the wealth." No structure was required within the teams. It was totally up to the members themselves how they were to divide responsibilities.

In an effort to introduce a degree of fairness for teams with different numbers of people, each application (NASA or otherwise) was to be a minimum of 50 rules per member. However, the resulting prototype had to be both self-contained and complete, regardless of how many rules it took. This encouraged students to carefully define the scope of their system so as to avoid over-extension. The largest system developed was approximately 200 rules for a two member team.

Due to the requirement for the students to identify and scope their own projects, work on the expert systems was not begun until around mid-term. Nevertheless, the two NASA applications were completed by the end of the semester.

There was no requirement as to the number of meetings with experts, but a record of all interviews was to be included in the documentation.

The project submittals were similar to those of the business course, except that there was no requirement for an executive summary. Instead, the following items were to be submitted:

- project report
- user's manual
- interview record
- logic diagram
- knowledge base print-out
- knowledge base diskette

Each team was to schedule an appointment with the instructor to privately demonstrate their system. Additionally, the NASA teams had to become available for an on-site presentation to NASA-KSC if required.

3.0 SAMPLE PROJECTS

A project team has worked in conjunction with NASA-KSC's Personnel Management Assistance Branch to develop an expert system prototype which

attempts to capture specialized knowledge concerning various aspects of NASA's employee retirement programs. The NASA retirement domain has recently been in a transition from the Civil Service Retirement System (CSRS) to the Federal Employee Retirement System (FERS). In addition, there is a third retirement plan, called "CSRS Offset," which applies in certain cases. The primary objectives of the prototype system were to determine which of the three plans is applicable to any given NASA employee and the impact of certain legislated retirement provisions on these employees.

3.1 Organizational Domain

The expected users of this system were defined to be specialists within the assistance branch who work with individual employees. This personnel group is a division of the Personnel Office that plans, organizes, and administers human resources programs for KSC's civil service employees. These employees consist of approximately twenty-six hundred professional, scientific, technical, administrative, and clerical people. Presently the FERS retirement plan provides benefits from three sources: A Basic Benefit Plan, Social Security, and a Thrift Savings Plan. Even if an employee leaves civil service before retiring, Social Security and Thrift Savings continue to work for the employee.

3.2 Expert System Solution

After study of the domain documentation and interviews with NASA domain experts, the extracted knowledge was organized using decision trees and backward chaining narratives for each of the provisions affecting retirement. Three domain experts participated during project development. The reason for multiple experts was that no single individual possessed all the specialized knowledge needed because of recent changes in the system. As a result of meetings with the experts, it was decided that the system should be diagnostic in nature and would identify the applicable retirement plan and examine legislation impacts on an employee's retirement. Prototype development was accomplished using Personal Consultant Easy.

The final system classifies an employee under a retirement program, and then evaluate the impact of three major legislations on the employee's retirement options. The finished prototype consisted of four knowledge bases: (1) RPD, the retirement plan determinator module; (2) CATCH 62, which identifies an employee's options regarding creditable military service; (3) WINDFALL, which determines the affect of windfall elimination on an employee's Social Security; and (4) GPO, which determines the Social Security reduction resulting from government pension offset legislation.

3.3 Project Assessment

The developed prototype evolved into a fairly complete and successful expert system. Future development goals should include additional verification to evaluate the current system and efforts to unify the individual knowledge bases into a "personnel assistant" which takes full

advantage of this technology. The resulting expert system could be a "fail-safe" personnel advisor which could be modified to allow an employee to "what if" various retirement options. This would require the employee to state some expectations of future economic conditions and for the personnel office to establish some heuristics for processing these expectations.

4.0 SUMMARY

This paper addressed and reported results of NASA-KSC and UCF mutually agreed upon student projects which were directed toward application problems in a variety of business and engineering domains at KSC. The primary objectives of this endeavor were to: (1) acquaint students with expert systems technology, (2) provide worthwhile learning experiences from actual work environment situations, and (3) to develop meaningful project results for NASA. The first objective was satisfied by traditional classroom lectures, readings, and testing. The other objectives were a more difficult challenge. Toward these latter goals, a number of successful expert systems business and engineering-related prototype applications projects were developed for NASA-KSC by UCF student project teams working with KSC domain experts and others.

This synergistic and mutually beneficial approach was made possible by the sponsoring grant provided by NASA. Future application development is now possible for those projects which demonstrate necessary technical and economic advantage over existing methods. For NASA and the various students involved in these projects this is a beginning, rather than an end, to a longer process.

5.0 ACKNOWLEDGMENTS

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Launch Vehicle Processing Simulation Assistant Expert System

Developers: David M. Cheney and Walter P. Haverstein
Expert: Dan C. Stout

Automated Data Processing Equipment Acquisition Plan Advisor

Developers: Richard A. Caliri, Martin L. Fillingim, Jr., Hugh Morris, and Ramona L. Woods
Expert: Melvin T. Hefter

NASA Retirement Expert System

Developers: R. Alan Collicott, C. Edwin Weatherford, and Gina C. Wilson
Experts: Craig Whittaker, Madeline S. Kennedy, and Frederick N. Bailey

Customer Requirements Identification System Expert System

Developers: Michael P. Aldrich, Heidi R. Hollowell, K. Peter Schmid, and Michael A. Vine
Experts: Dr. Alan E. Drysdale, William R. Munsey, David E. Headly, and Bruce D. Yost

Financial Accrual Data Expert System

Developers: Cathy Kahn Hasselberger, Martin Grimes, and Barbara Quaintance
Experts: Brenda B. Brooks, Robert M. Hebel, and James L. Jennings

LOX & GOX Ignition Source Expert System

Developers: Frederic D. McKenzie and Jenifer M. Sargeant
Experts: Cole J. Bryan and Floyd E. Lundy

Hazardous Gas Expert System

Developers: Cheryl E. Bagshaw and Taha A. Sidani
Expert: Gary N. McKinney

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