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A Framework of an Integrated Knowledge-Based System for Academic Advising*

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Academic advising has been found to be a key element in improving student retention and academic persistence. The objective of this study is to develop a framework of an integrated knowledge-based system that supplements and improves upon, a traditional academic advising system. A prototype intelligent academic advising system (IAAS) has been developed as a decision support tool with which students and advisors can efficiently coordinate and explore the best academic advice. The prototype presents the capability and efficiency of an integrated knowledge-based system by incorporating a database management system, a word processor, and other procedural modules. This paper also presents a framework of an academic advising network system (AANS) through extensions of the IAAS concept to the campus-wide computing resources and networks.

INTRODUCTION

A HIGH quality academic advising system is one of the key elements in a strategy to alleviate student retention problems. Baldridge, Kemerer, and Green [1] contended that advising, orientation, and counselling are important retention activities in college. Young, Backer, and Rogers [2] addressed the importance and impact of early academic advising for student development and retention. Other studies, Noel and Levitz [3] and Cope and Hannah [4], have revealed students' dissatisfaction with academic advising, and unpreparedness for academic choices. More recently, a poor faculty advising system has been identified as one of the chief causes of students leaving university before reaching their academic goals [5]. Baker [6] emphasized a diversified management strategy for the retention of undergraduate engineering students. His paper addressed a general consensus from the 1987 Noel/Levitz National Conference on Student Retention in Washington as follows:

> Retention is a very complex multifaceted problem which each institution must approach in its special manner ... Presenters at the conference generally agreed that each institution could improve its retention of students by improving quality, helping students meet their goals, keeping marketing promises, involving students in activities outside of the classroom, utilizing student's time effectively, and creating a favorable learning environment involving faculty, students, and administrators.

An academic advising system is designed to provide guidance for the successful accomplishment of a student's academic goal. This involves tracking of a student's academic standing, curriculum requirements, and alternative study plan within the context of academic policies and procedures. For both the student and the advising faculty, the advising process is a time-consuming, arduous task. Often the best alternative comes from the previous experience and knowledge of advising faculty or staff members. The advising knowledge, in most cases not in a text form, is a very valuable resource for a quality advising system.

The objective of this study is to develop a framework for an integrated knowledge-based system that supplements and improves upon a traditional academic advising system. The system is designed as a decision support tool with which students and advisors can efficiently coordinate and explore the best alternatives. The modelling process focuses on an integrated system architecture designed to extend and enhance the capabilities of a knowledge-based approach. Our prototype, intelligent academic advising system (IAAS), has demonstrated the feasibilities and advantages of an integrated framework. The framework for a campus-wide academic advising network system (AANS) is also presented as an extension of the prototype.

KNOWLEDGE-BASED APPROACH FOR ACADEMIC ADVISING

A knowledge-based system, or an expert system, along with a powerful reference mechanism, can implement a great advantage in retaining and disseminating rare and costly expertise leaving a more effective and efficient use of the human expert. The expert system is designed to abstract

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previous experience, information, and related databases in the form of defined facts, rules, and heuristics. Knowledge-based expert systems have proven to be excellent tools for a wide variety of applications which require capabilities in consultation, diagnosis, interpretation, instruction and control [7, 8, 9]. Valtorta, Smith and Loveland [10] developed a prototype rule-based expert system—the graduate course advisor (GCA). GCA assists students to determine the best course selection considering prerequisites and the student's academic history. The system adopts a modular structure to effectively manage four phases of the consultation: schedule length, legal courses, course evaluation, and schedule evaluation. Chan and Cochran [11] also reported similar expert-shell programs for graduate student advising system, called graduate student advisor (GSA). GSA consists of more than 100 rules that handle four areas of students' needs: requirements, options, available courses, and the faculty. Both GCA and GSA identified similar requirements in the advising process and developed rule-based expert systems, but did not consider the possibilities of improving the system with an integrated framework of expert systems. Intelligent Tutoring Systems (ITS) is another good example of a knowledge-based applications for the enhancement of a student's learning process [12, 13]. The pedagogical knowledge-base of expert teachers provides structural instruction and individual-based guidance in an interactive mode.

Another important consideration in expert system development is the modelling of an integrated software environment by incorporating existing capabilities, such as simulation, a database management system, a word processor, hypertext, graphics, and procedural languages. An integrated expert system environment extends the capability and flexibility of the expert system as well as coordinates data/knowledge manipulation. A number of articles address the enhancement of the expert system through a loosely coupled database management system, or a tightly coupled expert database management system [14, 15, 16]. The intelligent graphical user interface, and the design of hypertext structures are also important factors for the expert system implementation [17, 18]. However, only a few expert system modelling techniques emphasize the possible enhancement of the expert system by interfacing word processor capability [19]. Recent developments in PC-based expert shell programming languages greatly enhanced the flexibilty and versatility in the expert system development environment [20]. The separation of the knowledge-base from the inference engine remarkably simplifies the process of expert system development. To build an expert system, a developer simply creates a knowledge-base, and integrates it into the shell program. An expert system emulates the human reasoning by applying a specific knowledge-base and the inference mechanism. An inference engine imbedded in an expert shell provides a rationale for reasoning, as well as a number of system interfaces and utility modules. The reasoning process adopts either backward chaining, forward chaining, or a mixture of both.

Even though most universities maintain a registrar's database on mainframe computers, the system is not designed to address the needs of an advising process. Rather, they are designed to support a wide variety of academic administrative functions under a highly sophisticated, secure data scheme, thus, far beyond the access of both students and advisors. An easily accessible advising software, especially packed with a full capability of a knowledge-based system and advising information, has a great potential to improve upon a traditional advising system.

SYSTEM ARCHITECTURE

The IAAS framework has been designed to improve the capabilities and flexibilities of expert systems within the context of an integrated software including a database management system, word processor, and other procedural modules. The integrated software environment provides the capability of data-driven consultation along with database management and an interactive report generating function. Figure 1 presents a schematic diagram of the IAAS framework. The core of the knowledge-based system includes an expert shell program (VP-Expert™) which is interfaced with a database program language (Foxpro™), a word processor (WordPerfect™) and an external program, called the student advisors support module (SASM). SASM is written in 22 Pascal procedures and contains basic curriculum templates and course information. The compiled SASM modules are interfaced with the main expert program. A special utility program facilitates gateways among these software packages as well as optimizes the computer memory space.

VP-expert was selected because of its capability of calling external programs, backward/forward chaining, graphical user interface, hypertext management, and accessing external database files. Especially the graphical user interface provides a tool for the enhanced, mouse-driven window design, using special features called *dynamic images* and *smartforms*, which provide predefined graphical objects such as formfields, buttons, gauges, meters, etc. Foxpro facilitates a very flexible, extended database management capability as well as a gateway to the external programs. A memo field in Foxpro has virtually no limitations in terms of retaining text-based information. Our model utilizes the memo field as a tool for a continuing on-line acquisition of the growing knowledge-base. A word processor is also interfaced with both the expert shell and the database to assist the documentation effort as well as a concurrent consultation session. This unique feature of

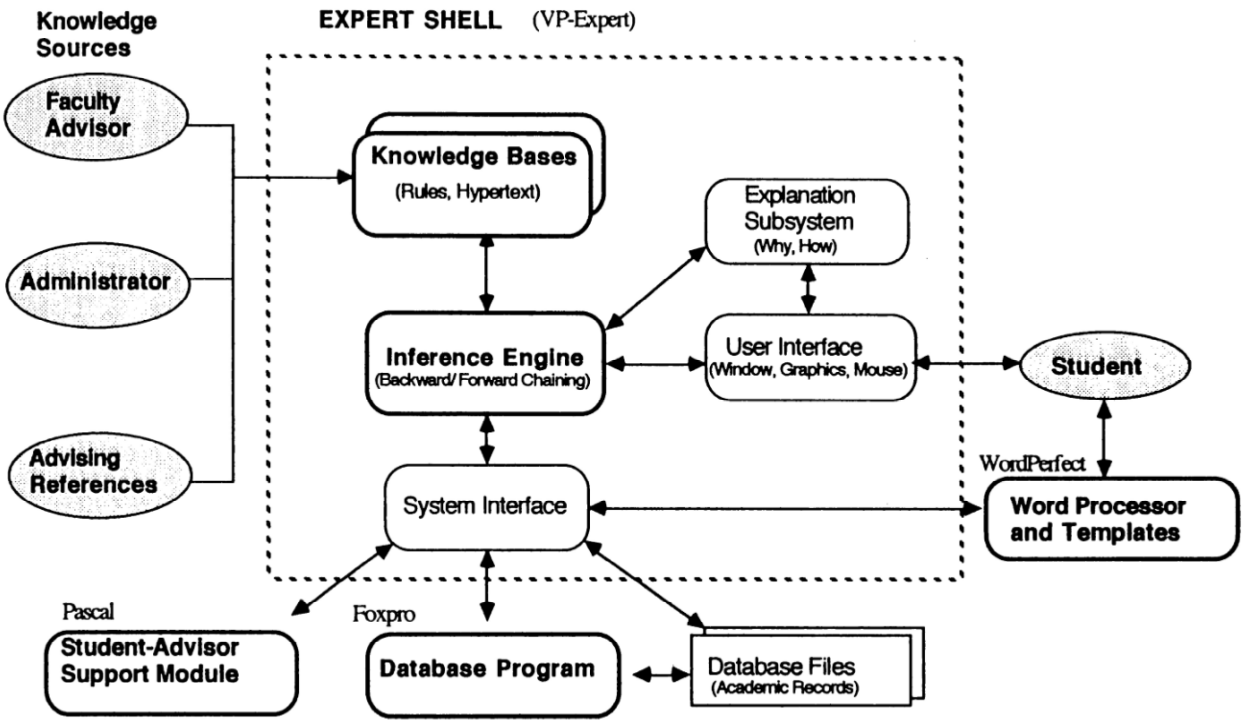

Fig. 1. Integrated knowledge-based system environment.

interfacing a word processor and a database management system greatly enhances the practical value of IAAS.

The IAAS expert module carries a domain-specific knowledge-base as well as relevant academic information, such as standard course templates, course information, prerequisites, technical requirements, information on tutoring, directory of advisors, and other available academic resources. The database and report formats have been designed to be consistent with the university central students record system. IAAS is an easy-to-use, menu-driven, portable, PC-based system. User interface is facilitated by the means of a mouse which can be used to select various options, using pull-down menus and buttons. The system also assists an advisor to keep track of a student's status through maintaining their records in an advisor's computer file.

KNOWLEDGE ACQUISITION AND REPRESENTATION

A knowledge-base is the very core of an expert system. It is the domain-specific knowledge that allows the system to act as an expert to deal with complicated problems using rules which emulate human judgement and heuristics. Knowledge acquisition is absolutely vital to maintain the integrity of the whole expert system. However, it is a well known fact that knowledge acquisition, or knowledge elicitation, is often a major bottleneck in expert systems development [21, 22, 23]. A framework for automated knowledge elicitation, verification, and the construction of a knowledge-base has been suggested as one approach [24].

Our initial effort was an extensive advising material survey and a series of interviews with advisors, administrators, and departmental staff members. The acquired knowledge has been organized and compiled as either expert rules or a part of narrative hypertext files. The structure of rule-based knowledge is described here first, then the hypertext part will be summarized in the following subsection.

Backward chained rules were constructed to perform an effective consultation through a coherent inferencing mechanism and advanced user interface techniques. Figure 2 presents a part of the hierarchical structure of the rule-based knowledge. Three layers of the knowledge structure present the meta-knowledge on top of the tree that controls the logistics of the reasoning process. At the bottom of the tree, the status information provides a basis for variable instantiations. The primary knowledge in the middle comprises the main body of advising rules, presented as nodes in the figure. Sample questions related to the node class are as follows:

SSHum: Have you completed social science humanity requirements?
If yes, and class = Sophomore and above, then
Does your course selection satisfy the depth req.?
Does your course selection satisfy the width req.?

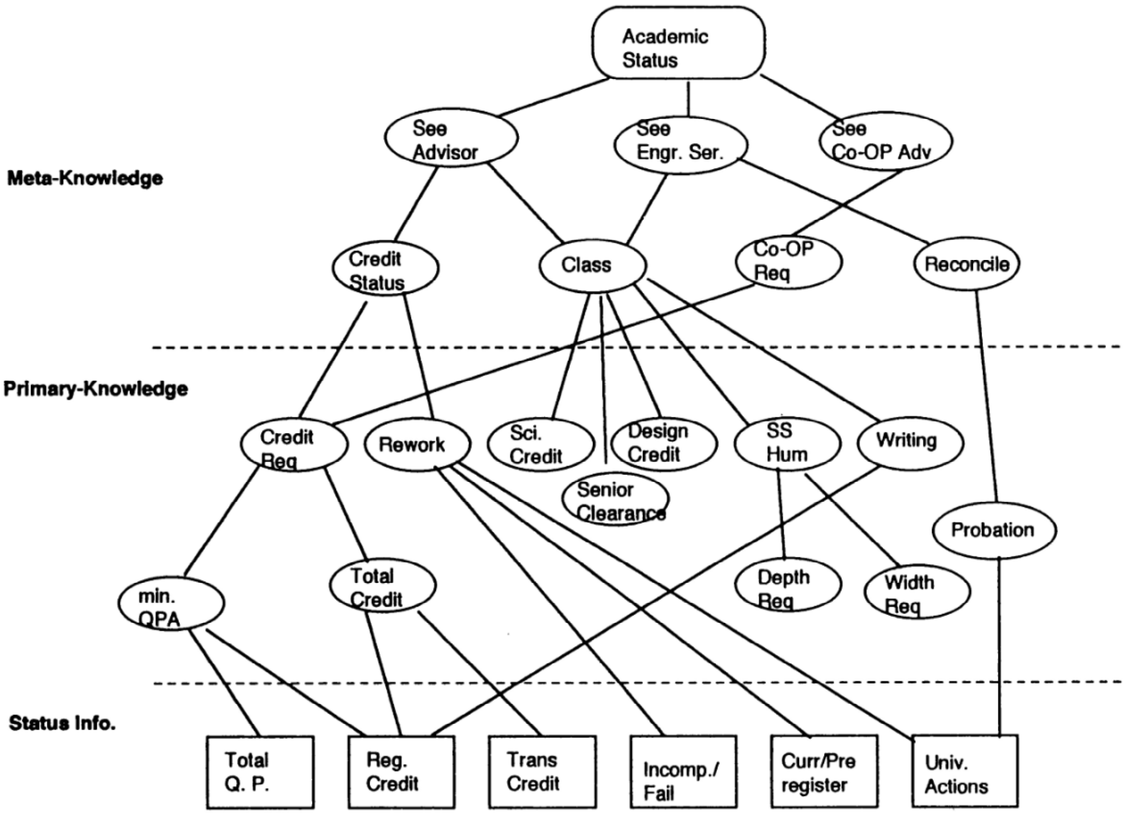

Fig. 2 Hierarchical structure of rule-based knowledge.

Design Credit:	Do you have enough engineering design credit? (if class = Middler and above)
Sci Credit:	Do you have enough engineering science credit? (if class = Middler and above)
Writing:	Have you completed your course for writing requirements? (if class = Junior and above)

The node *credit requirement* examines a student's quality-point average (QPA) status, based on the range of total earned quarter hours. If a student's QPA comes close to the brink of defined academic warning or probation, an appropriate statement of advice will be exhibited on the screen display. The expert rules are designed to deliver an early warning of poor academic performance. The early warning approach promises to provide a positive impact on the student's academic achievement. For example, the following rule number 201 will be fired upon a situation where the student's average QPA is lower than 2.1 and total quarter hours taken are in the range of 69 to 85.

```
Rule 201  credit_req_69_85
IF        TotalQH = 69-85 and QPA < 2.1
THEN      Awarn =found
          color = 7
          wopen 3,5,1,18,77,4
          active 3
          Display "
          Your current QPA standing is failing, or near failing.

          You will be subject to placement on ACADEMIC WARNING for minimum
          QPA 1.7, and subject to placement on ACADEMIC PROBATION for
          minimum QPA 1.5.

          Overall minimum cumulative QPA requirement for graduation is 2.0.
          A combination of two outstanding F grades, I grades, W grades or
          missing courses are also subject to same level of academic warning.";
```

The meta-rules are distinguished from the primary knowledge by their role for directing the reasoning required to solve the problem, rather than actually performing the reasoning. The meta-knowledge controls the sequence and execution of primary knowledge-bases. Three meta-rules govern a session by acting like an academic advisor, an administrator in the engineering service office, and a co-op advisor. For example, if a student's record indicates unresolved reconciliation, the meta-rule co-op adv directs the reasoning process to give the best advice at that point. Based on the result of a consultation session, the rule also recommends that a student see respective advisors or administrators. The relevant information, such as advisor's offices and conference hours, can be found in the hypertext file.

Hypertext files

Hypertext is a structured text/graphic file that allows the user to access necessary information through navigation of a logical path. The user can reach desired topics by simply clicking on highlighted keywords shown on the screen display, rather than a conventional, sequential searching technique. Each topic presents hierarchically structured information which leads to the in-depth details as well as other cross-referenced information. Since most current hypertext or hypermedia approaches are designed to aid the user passively rather than to force rule-based inferencing, it often finds a limited structure and processibility within an expert system environment [25]. However, a loosely structured format, rather than a fixed rule format, easily enlarges the volume of a knowledge-base to a great extent. Furthermore, with the aid of a simple external program, the hypertext file can be easily modified and appended. This structural flexibility of hypertext indicates a greater potential in compensating for difficulties in rule-based acquisition and representation.

Our hypertext approach systematically presents the information needed by a student or advisor during the advising session. Figure 3 exhibits a schematic diagram of hypertext elements within two major categories along with navigation function buttons. The general category includes basic information blocks such as IE office, transfer credit, academic standing, and tutoring. Several keywords systematically lead to the next category, course requirements area. Defining optimized logical paths and presenting appropriate keywords on a display screen is the most important task in a hypertext design. The optimized hypertext design provides an expert-guided knowledge presentation that delivers the most needed information quickly. This approach has a potential capability to break the aforementioned barrier in hypertext manipulation. For instance, the hypertext index screen displays a group of keywords that are relevant to senior students, such as senior clearance, student service, and a path to the course requirements category. This guided information encourages a senior student to prepare the senior clearance process at the office of student services, as well as review all the elective requirements for graduation. A junior or sophomore student is also motivated to browse through upcoming events in advance.

Four mouse sensitive buttons, namely the *Index* button, the *Help* button, the *Previous* button and the *Exit* button, expedite the information searching process. The hypertext files in our expert shell program are standard ASCII files. Even non-programmers, such as academic administrators, can easily update the file and disseminate it to the members of advising faculty for up-to-date, consistent advising guidelines.

SASM: a procedural module

SASM is an external module interfaced with the IAAS expert system, designed to assist students in managing and analyzing their academic records and academic standings. SASM is comprised of three submodules: a student transcript mainten-

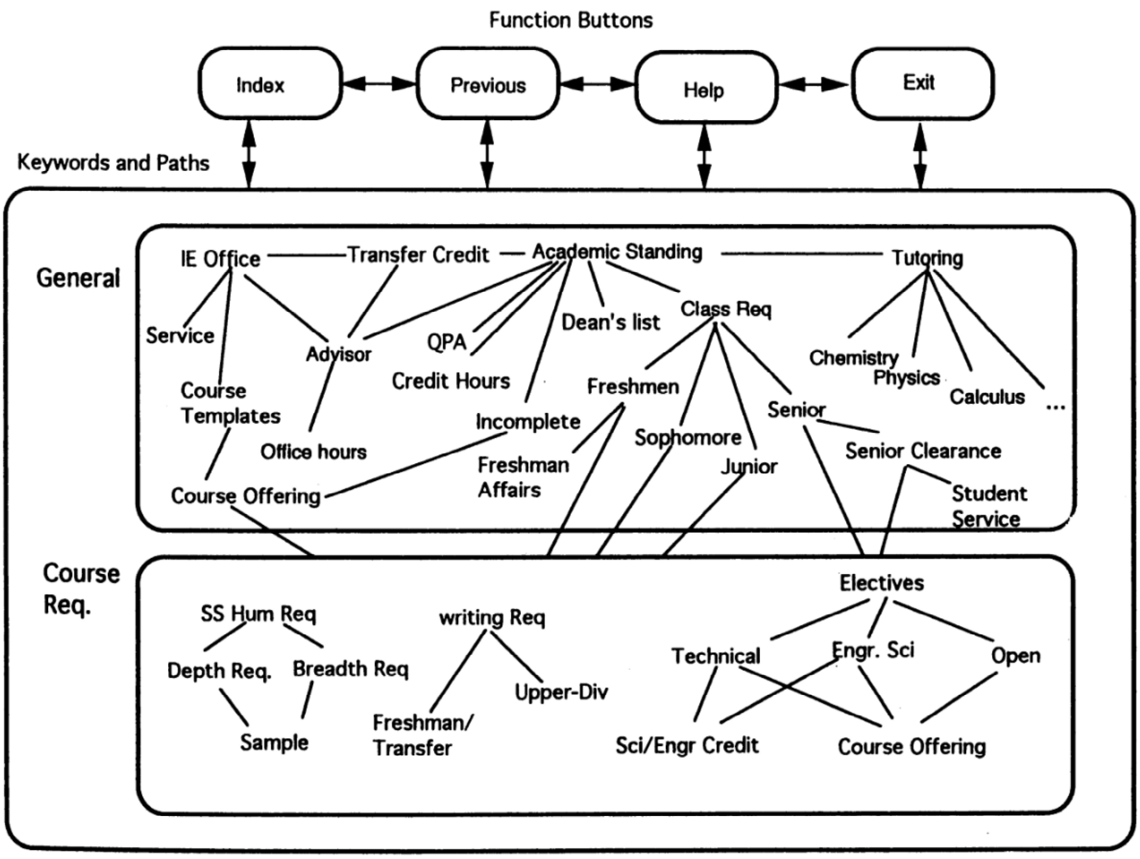

Fig. 3. Hypertext paths and function buttons.

ance submodule, an academic standing analysis submodule, and a report generating submodule. SASM is a user-friendly program that features menu windows with a light bar for selecting options, line-editing capability, and pop-up help windows.

During the first session, as soon as a student types in his or her biographical information, the system creates an appropriate course template on the student's diskette. The first submodule performs three functions:

(1) enter/update biographical information;
(2) enter/update course selection;
(3) enter/update grade data.

The biographical information includes student name, identification number, permanent and local addresses, year of graduation, major, minor, etc. The next two functions allow students to enter or update their course selections as well as course grades. The quarterly course templates are displayed on each screen in a chronological order while the cursor automatically moves to the next input area. SASM automatically provides the full course title when the user types in a valid course number. The module also verifies valid grade types as the user inputs the information on the screen display.

The second submodule provides the capability of academic standing analysis. The analysis includes calculation of current QPA, QPA prediction, and the degree requirement analysis. The QPA prediction provides a *what-if* analysis based on the expected or repeated grades in the coming quarters. This mode can also examine and match the student's course history against his or her major, as well as requirements defined by the categories, such as engineering science electives, technical electives, social science and humanity requirements, etc. Senior students use this capability to check their senior clearance status.

The third submodule assists students to produce three types of reports for further consultation with their academic advisor. The QPA report and the degree requirements report will be used as a guideline for the initial advising session.

IMPLEMENTATION

The goal of IAAS is to provide a decision support tool with which students and advisors can efficiently co-ordinate and explore the best academic advice. It emphasizes the capability of providing a timely advising session whenever a student needs it. The executable, compiled version of IAAS has been disseminated to the students on a single floppy diskette. The portable IAAS provides students with a preliminary advising session by analyzing basic academic standings. The IAAS system has been designed to improve two different aspects of an advising session. The first component, SASM, assists students in managing and analyzing their academic records and academic standings. The second component of IAAS provides a student with advice derived from the expert knowledge-base, and a well-prepared hard copy of a preliminary advising summary. When the student meets with his or her academic advisor with this preliminary result, both faculty and student can save time and effort using more accurate information. By reducing workload and redundancy, the academic advisor can improve the quality of the advising session. Furthermore, each student can save his or her entire academic records on a floppy diskette. This capability will motivate and encourage students to view their academic status more often, consequently seeing their advisor more often to make an important decision.

The IAAS prototype has been disseminated and tested among a group of students and advisors within the Industrial Engineering Department. From the viewpoints of the faculty, the students, and the administrators, the system is a welcome enhancement to the time-consuming traditional approaches to academic advising. Future extensions will include the incorporation of various academic forms and formal letters into the word processor to assist administrators and faculty advisors with their advising paperwork process.

ACADEMIC ADVISING NETWORK SYSTEM

The next step in the evolution of our advising system is to incorporate it into the large-scale networks of the university. We present here a framework for this larger academic advising system that incorporates campus-wide computing resources and network interfaces. Figure 4 presents a general architecture of a proposed Academic Advising Network System (AANS). At Northeastern University, several heterogeneous mainframe computers are tied through a campus network including an IBM system for general administration and a VAX system for the College of Engineering. The general administration computer provides access to the registrar's database which provides general academic information for each individual student. However, it was found that many advisors still use a very conventional advising technique without any help from the academic computer system.

The primary focus of the network-based academic advising system is the establishment of an efficient and effective distributed database management system within an expert system environment. Through the downloading or file transfer capabilities among the network computers, the system will eliminate the need for student's data entry for record keeping.

The gateway program between the mainframe computers and the personal computer facilitates the capability of file transparency. The file transfer from the mainframe to the personal computers will

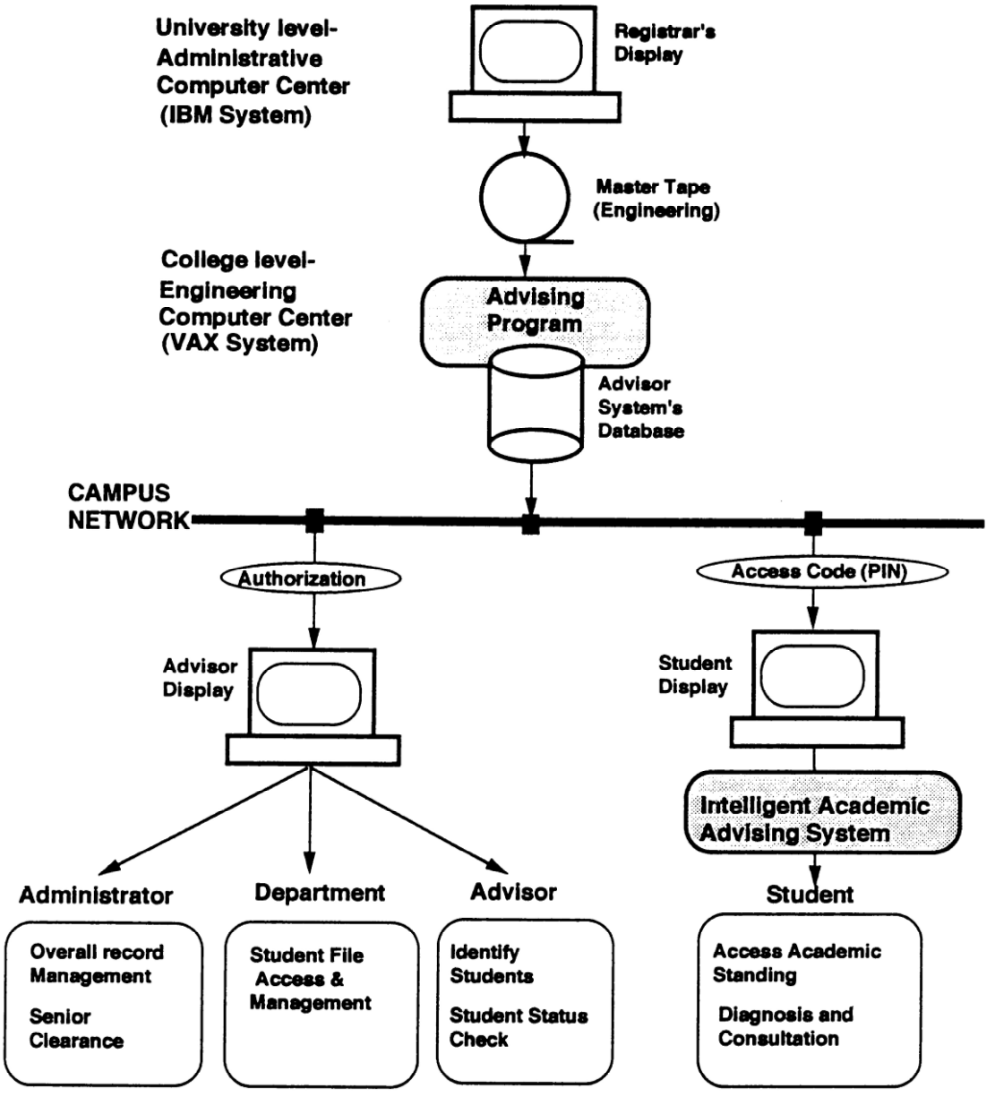

Fig. 4. Academic advising network system.

enhance the quality and accuracy of the advising procedure due to the up-to-date central records. The system also has to deal with secured data transfer and maintenance methods. As a security measure, it is suggested to create advisor system's databases for each college level by downloading the registrar's database. In the case of the College of Engineering, the downloaded database is maintained by the VAX engineering computer system which is connected to the hub of campus network. At the same time, a student can access his or her records through the IAAS module. In both cases a secondary security measure has been enforced by restricting access to the database through validated access codes such as an authorization code or a personal identification number (PIN).

The proposed AANS has to resolve many technical and systematic problems before full implementation of the system. A few major problems are:

1. effective interface with the existing administrative systems (registration, course scheduling, registrar's database, etc.);
2. adaptation to the different needs and requirements of each college;
3. adaptation to the heterogeneous computer hardware/software environments.

CONCLUSIONS

IAAS has demonstrated a paradigm of an enhanced student advising system utilizing integrated knowledge-based system environments. The system provides a foundation of enhancement of the traditional advising system by reinforcing the bridge between the students and their advisors. The knowledge-based early academic warning system combined with other academic status analysis capabilities demonstrates the possible contributions towards resolving the student retention problems. IAAS also presents the framework to enhance the quality and accuracy of advising through utilization of the up-to-date, consistent, expert advising knowledge-base. The acquired knowledge-base creates a foundation of standardized, consistent guidelines. The system has proven to be very beneficial for new advisors. The proposed campus-wide academic advising network system (AANS) will eventually extend the capability of IAAS to achieve a high quality academic advising system within the context of an expert information network system.

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