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An Expert System for the Scheduling of Hospital Beds

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This paper describes an innovative application of expert systems technology in the medical environment. The scheduling of hospital beds is a difficult but necessary task, and to overcome the problems faced in manual scheduling, an expert system has been developed to assist in, and improve the efficiency of this everyday task. A brief description of the system is given in this paper, together with the pragmatic considerations in the design and implementation of this system.

1. Introduction

Early medical expert systems were developed mainly for diagnostic and treatment applications, b recently, they have expanded to other fields of medicine as well [3, 5, 6, 11]. This paper describes a rule-bas expert system for scheduling hospital beds, with the objective of providing prompt and efficient service patients [4, 7, 8].

2. Current Problems

The Singapore General Hospital (SGH) has about 1600 beds shared by 30 wards. The scheduling beds is currently carried out manually in the various clinics of the hospital, which make individual be bookings independently of each other, although they share the same wards. While there is a bed manageme unit to cope with the scheduling of beds, it is still a cumbersome task to track the status of beds due to the la of a centralized booking system. Other problems such as over-booking and overflowing of patients in another ward also occur easily [8,10].

The process of bed allocation itself is complex due to various constraints such as:

a. segregation of male and female patients, adults and children;
b. beds reserved for the various disciplines (eg. orthopaedic);
c. matching patient admittance to operating doctor's schedule (operating dates, vacation, etc.);
d. 'elective' versus 'emergency' patients;
e. wards on 'oncall' schedules (some wards only admit patients on certain days).

Hence, hospital bed scheduling staff have to be well-versed with these procedures, and handle the fast as there are, on average, 200-300 admissions per day.

3. An Expert System Solution

An expert system has been developed to carry out the scheduling of hospital beds at SGH, and h resolves the problems mentioned above [4,7]. The system is able to:

a. schedule and allocate beds according to the various constraints and procedures dictated;
b. provide patients with the flexibility of defining a range of possible admission dates;
c. calculate the occupancy rate of the various rooms of the wards, and hence provide an even distribu of patients in the wards;
d. determine, and even out the workload distribution of the doctors;
e. differentiate between the handling of 'elective' versus 'emergency' patients; thus providing 'emergency buffer', i.e. reserve a certain number of beds for emergency cases;
f. allow for overflowing to other appropriate wards should a particular ward be fully occup according to 'overflow protocols'; and this is an option provided to the user;
g. provides various bed management/administrative functions such as cancelling or extending patie duration of stay, print or display various reports such as pre-admission listing of patients, doct operating schedules, current statuses of beds, wards, etc; and finally,
h. provide the user of the system with the option of doing bed scheduling automatically (i.e. by system), or manually, where the user keys in possible bookings, and the system checks through databases and confirms whether the selection is agreeable or otherwise.

4. A Sample Consultation

On running the system, the user is requested to enter the password, after which the Control Panel evoked. This displays the 5 menu options available, and the user selects the desired option by moving mouse cursor to the button, say, Module 1, and clicking (Figure 1).

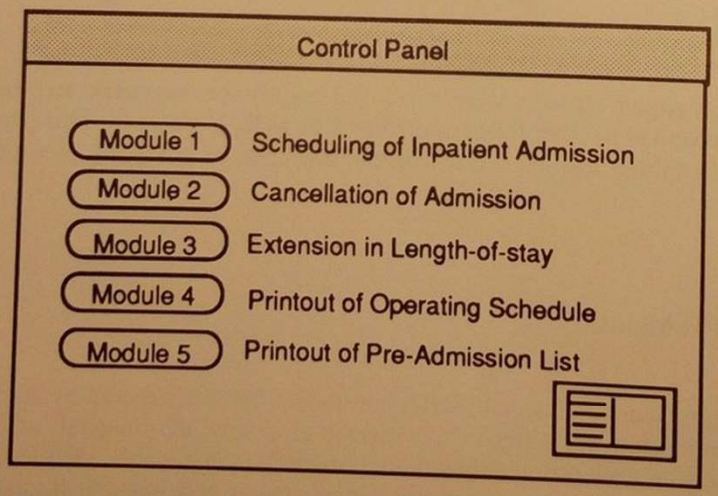

Figure 1. Opening menu or Control Panel.

When Module 1 is selected, an Inpatient Booking window will open to allow capturing of dat (Figure 2). The user is only required to enter data on certain mandatory fields that are used for scheduling (e.g class requested, admit type). The system will prompt the user if any data are omitted.

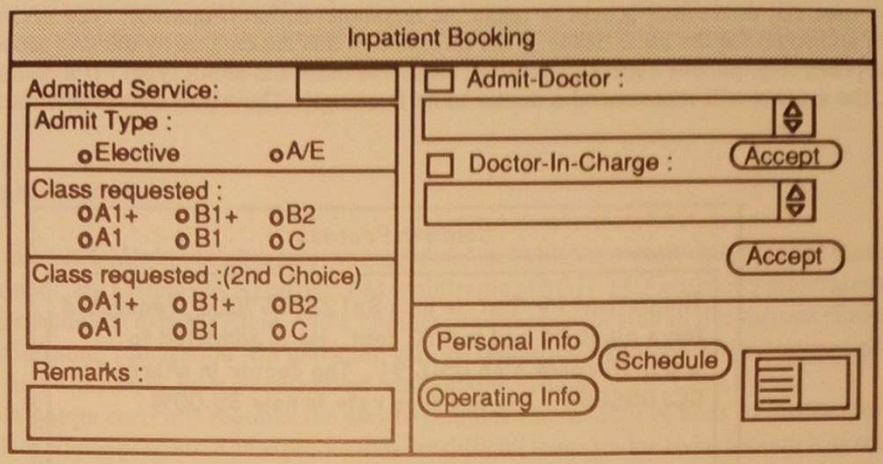

Figure 2. Inpatient Booking Window

Upon completion of data entry, the user clicks on the Schedule button and the Schedule Selection window is opened to allow the scheduling to proceed either in the automatic or manual mode. The manual mode is chosen if the user has a specific room for the system to check for admission possibility. Otherwise, the automatic mode is selected to let the system find a suitable room and a suitable admission date (Figures 3 and 4).

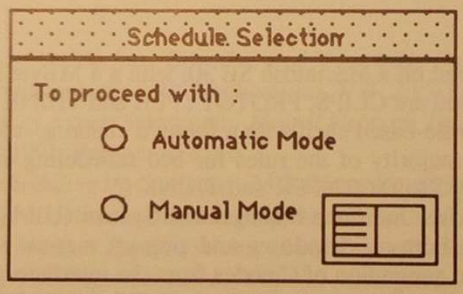

Figure 3. Schedule Selection Window

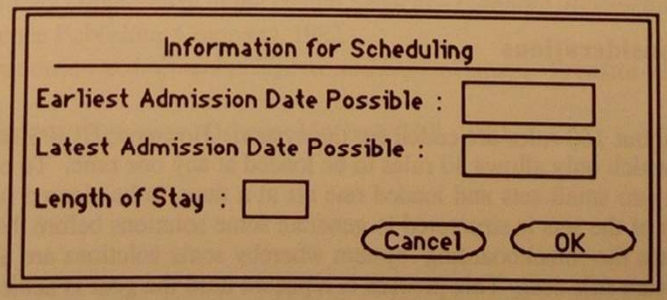

Figure 4. Information for Scheduling dialog box

The system will then search through all the relevant data files and rule sets before arriving at a suitable recommendation. The doctors' schedules, rooms and beds data, wards oncall schedules and patients records are some of the files processed here.

The user can then either accept or reject the recommendation (Figure 5). The system will indicate a possible date and room for the user. Some of the information that are entered by the user are also displayed for checking purposes (e.g. patient's identity number, requested class and admit type). If a doctor is not specified by the user, the system will recommend a doctor to be in charge. The whole consultation session takes about 30 seconds.

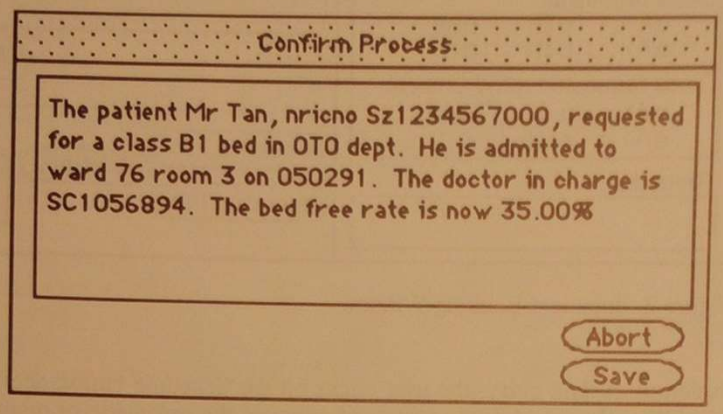

Figure 5. Confirm Process Window

5. Hardware and Software Platform

The system is developed on a Macintosh SE 30, with a 4 MByte memory, and an 80 MByte harddisk. The developmental software used are CLIPS, PROTOTYPER and THINK C.

CLIPS version 4 is a rule-based shell with a forward chaining inference engine. It is written in C, but has a LISP-like syntax. The majority of the rules for bed scheduling is coded using CLIPS, and the other functionalities are supported by PROTOTYPER and THINK C.

PROTOTYPER is a User Interface Management System (UIMS) software that allows easy creation of user interfaces with push buttons, windows and pop-up menus which are not provided by CLIPS. PROTOTYPER also allows the generation of C codes from the interfaces created.

THINK C version 4.02 is used to integrate both CLIPS and PROTOTYPER together. It also enhances the capabilities of both PROTOTYPER and CLIPS as these packages are not tailored for developing scheduling systems [9, 12].

6. Design Considerations

Altogether, about 160 rules are coded for the system. However, CLIPS (Macintosh version) has 32K static data limitation which only allows 30 rules to be loaded at any one time. To overcome this drawback, the rules are reorganized into small sets and loaded one set at a time, to be cleared from memory after the rules have been fired. Each of the sets is structured to generate some solutions before the next rule set is loaded into memory. This emulates the 'blackboarding' system whereby some solutions are used to infer other solutions, and load in other relevant rule sets. This process is repeated until the goal is achieved. A total of 15 rule sets have been built for this system.

To enhance the response time of the system, the data files have been divided into different related groupings; and the system opens only the files needed. This cuts down on the search time and memory requirements as the system does not have to perform a search through all the 1600 beds upon every request.

To further enhance the response time of the system, much procedural programming is done to handle repetitive search and to reduce the frequency of rules firing. The system uses rules mainly to match and instantiate facts. As such, the system utilizes and combines the benefits of both conventional and rule based systems.

The user interface is made as friendly and easy to use as possible. The system is designed to allow partial entry of data, and will only prompt the user to input certain mandatory data fields if they are omitted. Other non-essential information (from the point of view of the user) are placed unobstrucively in pop-up menus. Hence the user interface is geared towards a smooth and fast entry of data.

7. Future Enhancements

Plans are already underway to integrate the expert system (which currently operates as a stand alone system), with the existing Patient Care System (PCS) on the IBM mainframe at SGH. PCS currently maintains the various data files required by the scheduling expert system, and a number of terminals located in the various clinics and wards are hooked onto the mainframe. Integration will allow the various departments to check the statuses of beds, schedule patient admissions, and effectively, have a centralized bed booking system.

The expert system currently requires the user to estimate the number of beds to reserve for the emergency buffer and the length of stay of patients. These predictions are difficult to make due to factors such as seasonal demands of certain beds and epidemiological patterns of certain diseases. A future enhancement to the system could be to add modules (perhaps using neural networks) that can learn and make such predictions [1,2].

In order to minimize system maintenance, the rules sets could be designed to be more generic. A number of data files could be created to store variable data separately, instead of being coded into the rules sets. Any changes could be easily made to the data files, thus leaving the rules sets untouched. The system may also be modified to cater to other hospitals, merely by changing the relevant organizational structure (e.g. of the wards) and scheduling criteria, but the core of the system remaining the same.

8. References

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