Applications of Computer Simulation in Medical Scheduling

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Abstract

In current health care service, it's important to minimize staff idle time and maintain a high utilization rate of the medical facilities. More and more hospitals, however, recognize waiting is a universal and serious problem for patients. The critical problem in medical scheduling is how to keep the balance of all these factors. Computer simulation is a powerful tool for medical management and scheduling. This paper presents a literature review of the current state of computer simulation in medical scheduling. Various approaches to simulate the operations in medical area, as well as analysis of these approaches along with their effectiveness are presented in this paper. We anticipate such a survey would help us to develop a computer simulation system for use at Duke University's medical oncology department.

1. Introduction

In today's medical care, reduction of health care cost is of paramount importance. [1] Health-care managers pay much attention to the keep as little idle time for staff and as high utilization rate of the facilities as possible. On the other hand, patient waiting is recognized as universal and serious problem. [2] Simulation is a powerful management tool to solve these problems. [3]~[6]

Mahachek [3] proposes, with today's software for personal computers, that simulation is no longer just for academics and consultants. He argues that high and mid-level managers should actively seek out simulation as a problem-solving technique. He provides these health-care managers with the fundamental knowledge needed to individually initiate simulation studies of their departments. He proposes that analysts, software packages, and computers are three basic resource requirements for a simulation project. He also proposes that simulation will encourage new ideas, reduce organizational friction and lower the risks associated with the implementation of changes. He emphasizes the final usefulness of a simulation depends more on managers' motivation and participation than analyst's talent. He proposes a guideline to build up a general simulation system of patient flows. The first step of simulation is the validation of simulation model of current system because that model would be the baseline. The second step is to analyze the sensitivity of the system--those variables to which the model is very sensitive should be taken extraordinary care to be measured in a true magnitude range, and those variables to which the model is insensitive didn't need much time to collect data. The third step is to use this simulation model and test changes on simulations.

Boxerman proposes the use of simulation modeling as a powerful tool for testing alternatives and process improvement. [5] He proposes that the first step in the simulation modeling process is the development of a process chart depicting the elements of the real world system and their interconnections. Once the process chart has been constructed, additional data will be collected for each step in the process. The third step is to design a decision-maker to support the simulation modeling process. Once the system has been tested, the next step in the simulation process is the actual simulation "run". This step consists of a large number of executions of the program's logic flow, where each iteration corresponds to one "trial" of the system. In searching for a way for process improvement, a major virtue of tested simulation modeling is the problem solver's ability to examine the consequences of making changes.

2. Computer Simulation in Emergency Department

Because of the complex features of these departments, such as queuing, various levels of preemptive priority among patients, multiple servers with variable service times dependent on the level of patient priority, and nonstandard statistical distributions of patient arrivals, traditional operations research and management techniques are of limited usefulness for large emergence department. Computer simulations allow much more accurate modeling of these systems, including transient conditions using random arrival and service times with realistic statistical distribution, however, it's an ideal tool for predicting the results of system alterations. [6][7]

Saunders et al. developed a computer simulation model of emergency department operations with SIMAN language. [7] A discrete-event simulation model is developed in which patients' personnel, or resources change at discrete points in time. This system uses multiple levels of preemptive patient priority. Each patient would be assigned an individual nurse and physician. All standard tests, procedures, and consultations are incorporated. During the simulation, selected input data, including the number of physicians, nurses, treatment beds, and blood test turnaround time are varied systematically to determine their simulated effect on patient throughput time, selected queue sizes, and rates of resource utilization. The dynamics of the emergency department care process are modeled by means of a flow diagram depicting patient movement among stations or events. At each substation in the emergency department care process, the duration of each wait is randomly distributed. Input data probability distributions are based on actual historical data. Only one factor at a time is varied in the simulation. Hence, the experimental design is a one-way analysis of variance. With their simulation model, the authors argue that emergency department can be simulated using advanced computer simulation software. Also they demonstrate the model's ability to estimate output data such as patient throughput times, queue sizes, and resource utilization rates.

3. Computer Simulation in Pharmacy Department

Ishimoto et al. propose a computer simulation of the dispensing work performed in a hospital pharmacy with a goal to optimize the assignment of pharmacists based on the number of prescriptions. [8] Prescriptions are randomly sampled from classifications based on season and day of the week. The number of pharmacists is fixed. The time from 9:00 to 13:00 is divided into 10-minute intervals. The frequency of combination of several dosages is analyzed based on the sample, and the dispensing time is calculated based on a statistics equation. Though the dispensing work is continuous, authors find the 10-minute unit simplified the simulation. As a result of the simulation, authors found that it's possible to predict fairly precisely the number of pharmacists required to complete that work. The method also enables the users to assign the optimum number of staff for dispensing duties according to the estimated number of prescriptions and the optimum waiting time of patients.

Unlike last paper, Vemuri pays more attention to the patient waiting instead of the efficiency of pharmacists. [9] He developed a computer simulation to study the cost of various operations for reducing patient waiting time in pharmacy. The time required to complete prescription filling is recorded for baseline of five pharmacy employees. A fixed factorial design of twelve configurations is used in which the number of different types of pharmacists is varied. Poisson arrival is used as the queuing model and patient waiting time for each configuration is determined through computer simulation. Pharmacists' salaries are used to calculate the relative cost. Without distributing the operation of the pharmacy, author uses computer simulation in identifying the least expensive method of reducing patient waiting time.

4. Computer Simulation in Operating Room

The single largest cost to a hospital delivering surgical care is incurred in the operating room. Managers are concerned about how to improve the utilization rate of operating room facility and staff. Computer simulation is used to make a better schedule of the operating room. [1] [10]~[19]

Dexter et al. argue that, since salaries of operating room account for most operating cost, operating room managers must try to maximize "labor productivity" by using the least number of staff necessary to care for the patients. [10] Because labor costs are fixed at operating room suites, the managers must maximize the utilization of operating room. The authors also propose that determining the appropriate amount of bock time to allocate to surgeons and selecting the days on which to schedule elective cases can maximize operating room use. They develop a computer simulation of patient scheduling. Each computer simulation is performed with a different combination of five input parameters: scheduling algorithms, average case duration, average patient's waiting time, hours of block time each day, and numbers of blocks each week. The output is the average operating room utilization. They find the operating room utilization depends greatly on the average length of time patients wait for surgery.

5. Computer Simulation in Out-Patient Department

Simulation analysis has been utilized by many researchers to investigate various outpatient services. [2][20][21] Goitein proposes a simple example of waiting time analysis with Monte Carlo simulation. [2] The author states, though many factors must play a part in determining whether and for how long patients wait, the predictability of the length of consultation is certainly a major factor. When the consultation can be kept to a fixed time, patients can be confident that their appointment will start on schedule. Conversely, consultations of variable and unpredictable duration, and contain large fluctuations in the length of consultations may lead to long delays for subsequent patients. The author develops a model started with an appointment schedule to be analyzed and then traced the experience of a large number of patients, allowing for fluctuations in the duration of consultations, the possibilities of unscheduled emergency consultations, and fluctuations in the patients' arrival time. The fundamental parameter in the model is the "booking factor", the ratio of the scheduled interval between scheduled appointments to the actual average duration of those appointments. In the model, the numerical results are proportional to the average length of consultation, and 20 minute is used as the average length of consultation. The nominal duration of a consultation is taken to be unity, i.e., it is considered to be the fundamental unit of time to which all other times are scaled. The patients are assumed to arrive on average 5 minutes before their scheduled appointment and the normal distribution is considered to have a standard deviation of 8 minutes. Appointments are scheduled at intervals calculated by multiplying the booking factor by the nominal consultation time and a physician is assumed to be on time. The two main results are the patient's average waiting time and the physician's idle time per patient are reported. The result of the simulation suggests that a good schedule would use a booking factor of approximately 1.08.

6. Application of Computer Simulation in Training

Schwarz proposed a scheduling database for training programs for psychoanalytic institute, which stored scheduling records and generated schedules and letters informing students, supervisors, and advisors of deadline. [22] The Author argues that poor knowledge of interdependence within the system is a reason of soaring costs, dissatisfied patients and unduly stress staff, and management game is an approach to make most of the required knowledge. It introduces a PC-based management game dealing with scheduling and sequencing operations in hospital departments, which uses a process-oriented approach for simulation. The players have to first define their goals first. During the game, the teams can lay down operation routines, change their appointment systems and make staff and investment decisions. There are two parts in a hospital, diagnostic and therapeutic departments, as well as wards. After admission, the patients are either sent directly to the wards or have a first examination in a medical department. The medical treatment itself is a function of the patient's diagnosis. A simplified model, however, is used to simulate the real world.

7. Summary

From above discussions of computer simulation in medical area, we can find there exist following steps to build up a computer simulation model for patients:

1. Analysis of patient flow
2. Collecting data—patient classification, arrival time, waiting time, interview interval, etc.
3. Construct simulation model, including random event generator
4. Validation of system model
5. Change configuration, test changes
6. Result analysis

However, a usual shortcoming of these papers is lack of theory base and the technique used in simulation is too simplified—the most usual method used is to set up several variables, and just run the simulation program in a large number of configurations. Another problem is that rare papers consider the patient scheduling with facility and staffing scheduling together.

The scheduling in Medical Oncology department is a complex one—all of the sub-departments such as out-patient, operating room, radiation, etc., are coupled together and need to be considered in the modeling, which suggests that a more complex model needs to be considered in such an environment.

Conclusion

Traditional approaches of scheduling such as operations research are of limited usefulness in the medical scheduling. The scheduling problems in medical area are more complex than those used in industry or transportation area in that here the human factor has to be considered. Computer simulation is a powerful tool for medical management. This paper presents the applications of computer simulation in the medical area, as well as the analysis of these approaches. At last, We discuss the potential application of computer simulation in the medical oncology department.

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