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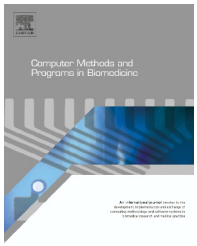

Scheduling prioritized patients in emergency department laboratories

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ABSTRACT

This research focuses on scheduling patients in emergency department laboratories according to the priority of patients' treatments, determined by the triage factor. The objective is to minimize the total waiting time of patients in the emergency department laboratories with emphasis on patients with severe conditions. The problem is formulated as a flexible open shop scheduling problem and a mixed integer linear programming model is proposed. A genetic algorithm (GA) is developed for solving the problem. Then, the response surface methodology is applied for tuning the GA parameters. The algorithm is tested on a set of real data from an emergency department. Simulation results show that the proposed algorithm can significantly improve the efficiency of the emergency department by reducing the total waiting time of prioritized patients.

1. Introduction

Accurate and quick treatment of patients is the most important aim of the health care systems [1], especially at emergency departments, as such departments are dealing with life and death situations on a daily basis, an inefficient patient treatment procedure can end up in pernicious results. After shifting the patients to emergency department, their initial information is taken by a nurse and then, they are categorized according to the severity of their conditions in order to determine their treatment procedure. Some patients may need to go to emergency laboratories to take some medical tests. Scheduling and coordinating the patients in the emergency laboratories in an efficient manner has a major role in improving the performance of the emergency department and providing a more reliable system. In this way, the priority of the patients determined by a triage factor becomes important. Triage is the process by which the urgency of the patient condition is determined. The assessment of the patients' medical needs is usually performed by a triage officer using an established plan or system which consists of 5 levels [2,3]. For each level of the triage factor system, a related weight in form of special number is assigned to a patient by an expert who takes the information about the severity of each patient health condition; the higher the weight is, the most severe the patient health condition is. The aim of using triage is to protect endangered human lives by granting priority to the most urgent patients with immediate needs while paying enough attention to other patients in order to attain the most overall outcome of the available resources [4].

In this research, and as a real case study, an emergency department of a hospital is studied, which uses the five-level triage system. The aim of this study is to improve the efficiency

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of the emergency department by minimizing the total waiting time of prioritized patients in the emergency department laboratories. Since the environment of emergency department is based on accidental entrance of patients who suffer from an accident or are in a critical state, for some patients who need medical tests at laboratories, the tests do not usually require any predecessor action (such as fasting before taking tests, etc.). Additionally, at most laboratories, there is no predetermined route of tests for patients' tests. Hence, the emergency department patients scheduling at laboratories can be formulated as an open shop scheduling problem. Open shop scheduling problems mainly consist of processing n jobs on m machines without any pre-determined sequence of operations. Moreover, in real world situations, in most of the production floors and even in laboratories, we seldom see just one machine (place) for processing one job. While classical open shop scheduling models commonly consider only one machine at each stage for processing a job, in flexible open shop scheduling models, there may be more than one machine at each stage to increase the throughput and capacity of the shop floor, to balance the speed of the stages, to either eliminate or to reduce the impact of bottleneck stages on the overall shop efficiency [5]. The laboratories we consider can have parallel places or multiple staff for doing the same test. The objective of scheduling patients in the emergency department laboratories is to minimize the total waiting time of the patients with emphasis on their triage factor which leads to minimizing total weighted completion time of jobs in a flexible open shop scheduling problem.

Since open shop scheduling problems are categorized as NP-hard problems [6,7], there is no exact method which can be used for solving real-sized problems in a reasonable amount of time. In this research, a genetic algorithm (GA) is proposed as a solution approach. Response surface methodology as an efficient tool is employed to optimize the GA parameters. The algorithm is then tested on a set of real data collected from an emergency department to show the efficiency and superiority of the proposed method.

The remainder of this of this paper is organized as follows. The related literature review is provided in Section 2. The mathematical model is presented in Section 3. Section 4 describes the proposed genetic algorithm. In Section 5, the efficiency of the proposed approach is investigated and finally, Section 6 draws some conclusions from this study.

2. Literature review

In recent years, health care systems scheduling has caught a great deal of attention from the operations management community. Previous research in this area can be categorized into two main groups: patient scheduling and resource (e.g. staff) scheduling. Patient scheduling is recognized to have a major role on the performance of the health care system by reducing the waiting time of the patients and facilitating consecutive treatments without interruption [8]. Demeester et al. [9] have proposed a hybrid tabu search algorithm for minimizing the weighted sum of the total penalty incurred for assigning patients to un-preferred rooms and the number of transfers considering medical needs of the patients as well as their preferences. Min and Yih [10] have proposed a stochastic dynamic programming model for scheduling patients in a surgical facility with limited capacity, taking into account patients' priority. Tai and Williams [11] have modeled the patient unpunctuality in appointment driven outpatient clinics by a constructed F3 distribution, taking into consideration various patient behavior patterns. The aim of the proposed model is to minimize the total waiting time of patients and the doctors. Fiegl and Pontow [12] have developed an algorithm for scheduling pick-up and delivery (PD) tasks in hospitals in order to minimize the average weighted flow time. They have modeled the problem by using the methods of graph theory. Alexopoulos et al. [13] have modeled and simulated the stream of patients arriving at a community clinic. They have proposed a nonhomogeneous Poisson process to model the random patients' arrivals and an unbounded Johnson distribution for patients' tardiness. Chien et al. [14] have modeled the problem of rehabilitation patient scheduling as a hybrid shop scheduling, and developed an evolutionary approach based on genetic algorithm to solve the problem. The objective is to increase the service quality by reducing patient waiting time and therapy equipment utilization. Petrovic et al. [15] have presented a multi-objective optimization algorithm for scheduling radiotherapy treatments for categorized cancer patients. The objectives of the proposed model are minimization of average patients' waiting times and minimization of average length of breaches of waiting time targets. Turkcan et al. [16] have used a constraint-based approach for developing sequential appointment scheduling with service criteria and some other criteria such as expectation and variance of patients' waiting times, queue length, and over time. The proposed measure is the minimization of the difference between maximum and minimum expected waiting time of patients, and the number of patients at the beginning of each slot. Kiris et al. [1] have developed a knowledge-based reactive scheduling system for emergency departments, considering patients priorities, arrival times, flow time, and doctors work load, for the aim of determining the patients who have higher priorities initially, and then minimizing their waiting times. Pennathur et al. [17] have presented an elective model of patient-tracking system simulator which combines a realistic model of emergency department and patient events with a configurable patient-tracking system display. Adan et al. [18] have developed a two-stage planning procedure for master planning of elective and emergency patients under stochastic demand and capacitated resources. They have applied a goal programming approach to minimize the deviations of the resources consumption to the target levels of resources utilization in order to obtain a tactical plan. Lu et al. [19] proposed an adaptive clinical treatment processes mechanism through recommendations, which determines appropriate treatment plans for particular patients. Each treatment plan is indexed by a set of significant patient features. In some other papers like Meyer et al. [20], the importance of utilizing an efficient data management system is stressed, and for this aim, a complex data model is developed and implemented using oracle database in high availability cluster mode in order to integrate different types of participant-related data. Demir et al. [21], focused on emergency readmissions, and by utilizing a multilevel