UNIVERSITI PUTRA MALAYSIA

LOCAL SEARCH APPROACHES FOR PATIENT SCHEDULING PROBLEM IN PARALLEL OPERATING THEATRE

NUR NEESHA BINTI ALIMIN

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LOCAL SEARCH APPROACHES FOR PATIENT SCHEDULING PROBLEM IN PARALLEL OPERATING THEATRE

By

NUR NEESHA BINTI ALIMIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2020

DEDICATIONS

To my beloved families,
thank you for all your love and support.

LOCAL SEARCH APPROACHES FOR PATIENT SCHEDULING PROBLEM IN PARALLEL OPERATING THEATRE

By

NUR NEESHA BINTI ALIMIN

December 2020

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Faculty: Science

Patient scheduling in operating theatres (OT) involves high costs to hospitals and may affect treatment and satisfaction to patients. Scheduling for patients in parallel OT can help to schedule a large number of patients and emergency patients are considered in this study. Other than that, emergency patients are able to be scheduled and treated on the day as the modification of schedule is performed during the dynamic process of scheduling. The objective of the study is to propose different types of local search which are local search (LS), improved local search (ILS) and mixed local search (MLS) for solving patient scheduling problem in parallel OT.

This study presents two phases of scheduling where initial schedule of regular patients is obtained in the first phase, then scheduling process continues in the second phase when operations start and emergency patients arrive. In the first phase, pre-processing stage, combination of pre-processing stage with low-level heuristic and genetic algorithm are used. The different types of LS are applied in the second phase of scheduling. Tests are conducted for the proposed methods to look for a method that has the ability to prevent delays of patients with a lower total cost. The performance of the LS is compared with zero-one programming method from literature and it is reliable to the problem. The result of ILS has reduced the average total cost to 30.4% while MLS has achieved 52.7% decrease in the average total cost. The computational results show that MLS outperforms both methods of LS and ILS by minimizing the total cost of OT greatly.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENDEKATAN CARIAN TEMPATAN BAGI MASALAH PENJADUALAN PESAKIT DALAM BILIK BEDAH SELARI

Oleh

NUR NEESHA BINTI ALIMIN

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Penjadualan pesakit di bilik bedah (OT) melibatkan kos yang tinggi terhadap hospital dan boleh mempengaruhi rawatan dan kepuasan kepada pesakit. Penjadualan untuk pesakit OT selari dapat membantu menjadualkan sebilangan besar pesakit dan pesakit kecemasan dipertimbangkan dalam kajian ini. Selain itu, pesakit kecemasan dapat dijadualkan dan dirawat pada hari tersebut kerana pengubahsuaian jadual dilakukan semasa proses penjadualan yang dinamik. Objektif kajian adalah untuk mencadangkan pelbagai jenis carian tempatan iaitu carian tempatan (LS), carian tempatan penambahbaikan (ILS) dan carian tempatan campuran (MLS) untuk menyelesaikan masalah penjadualan pesakit dalam OT selari.

Kajian ini mengemukakan dua fasa penjadualan di mana jadual awal pesakit biasa diperoleh di fasa pertama, kemudian proses penjadualan disambung pada fasa kedua ketika operasi dimulakan dan pesakit kecemasan tiba. Pada fasa pertama, peringkat pra-pemprosesan, gabungan peringkat pra-pemprosesan dengan heuristik tahap rendah dan algoritma genetik digunakan. Pelbagai jenis LS digunakan pada fasa kedua penjadualan. Ujian dilakukan untuk kaedah yang dicadangkan untuk mencari kaedah yang mempunyai kemampuan untuk mencegah kelewatan pesakit dengan jumlah kos yang lebih rendah. Prestasi LS dibandingkan dengan kaedah pengaturcaraan sifar dari literatur dan LS bersesuaian untuk masalah tersebut. Hasil ILS telah mengurangkan purata kos keseluruhan hingga 30.4% sementara MLS telah mencapai penurunan 52.7% dalam jumlah keseluruhan kos. Hasil keputusan kajian ini menunjukkan bahawa MLS dapat mengatasi kedua-dua kaedah LS dan ILS dengan mengurangkan kos keseluruhan OT.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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This is to confirm that:
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LIST OF ABBREVIATIONS

CPU	Central Processing Unit
GA	Genetic Algorithm
ILS	Improved Local Search
LS	Local Search
MLS	Mixed Local Search
OT	Operating Theatre
ZOP	Zero-one Programming

CHAPTER 1

INTRODUCTION

1.1 Research Background

Combinatorial optimization is a field that is used to find the maxima or minima of an objective function from a finite set of objects. It is closely related to operations research where it involves algorithms to solve for problems. Some examples of combinatorial optimization problems are packing, routing, resource allocation, planning, scheduling and others. This research focuses on scheduling problem in healthcare which is scheduling for patients in the operating theatre (OT). Numerous researchers have conducted research for scheduling OT such as Fei et al. (2008), Liu et al. (2011), Vancroonenburg et al. (2015) and others. Further discussions related to the scheduling problem are presented in Section 1.1.1 to Section 1.1.4.

1.1.1 System in Healthcare

The healthcare system is related to organizations, people and resources that render healthcare services. Healthcare industry faces challenges in providing services that give satisfaction to patients and also on the healthcare expenditures (Gupta and Denton (2008)). An essential facility that needs to be operated efficiently is the system of OT scheduling as it is one of the largest cost consumption in a hospital. Hence, scheduling is an important problem that needs to be managed properly in order to utilize the resources and provide the best schedules at lower cost.

1.1.2 Scheduling of Operating Theatre

Scheduling of OT is one of the combinatorial optimization problem and it is the most popular topic in the healthcare industry. OT scheduling involves scheduling for patients according to their planning duration of surgeries. One of the aspects related to OT scheduling is patient priority where patients are scheduled depending on the priority rule. Regular and emergency patients are to be considered in OT scheduling. Generally, emergency patients need to be scheduled immediately as soon as any OT is available since their priority level is higher than regular patients. Other aspects includes capacity of resources, eligibility of OT and limitation of the OT available.

In the case of OT scheduling that involves emergency patients, the situation may cause patients to be delayed during the scheduling process. This problem arises due to sharing of OT to schedule for regular patients and emergency patients that arrive

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on the day.

1.1.3 Offline Scheduling

The offline scheduling of OT involves the planning of regular patients to be scheduled in advance. Regular patients are often differentiated between inpatients and outpatients. Inpatients are patients that are admitted to the hospital before surgery or arrive on the day of surgery, while outpatients are patients that go to the hospital for appointments or surgeries and leave on the same day. Most research did not state the type of patients considered, but generally for offline scheduling, patients that have provided their information in advance are considered.

1.1.4 Online Scheduling

Online scheduling of OT is the process of scheduling that needs modification during the process until the schedule is fully executed. The causes of modification are usually due to unforeseen situations such as arrival of emergency patients, cancellation of surgery or complications during surgery that requires longer time. This study discusses emergency patients that need to be scheduled as soon as possible when other surgeries are running on the day. This situation may lead to the delay of regular patients that have to be scheduled to another day because emergency patients become the most prioritized patients on that day. The arrival rate of emergency patients is usually generated by probabilistic distribution. Stochastic programming also can be used but studies show that this technique has limitations in practice (Samudra et al. (2016)).

The involvement of emergency patients may also cause an extension in time duration on the usage of OT for that day. These two situations will result in high cost consumption if the scheduling problem for the regular and emergency patients is constructed poorly. Therefore, an efficient schedule with minimum cost consumption is important for contributing the best services to patients and achieving great management of the facilities in the hospital.

Generally, patient scheduling in this study consists of two phases. The first phase is offline phase where regular patients are scheduled and the list of initial schedule is ready before they go through operations. The second phase is online phase which is considered a difficult phase because the schedule involves emergency patients that arrive on the day and they have to be scheduled in the OT as soon as possible. Scheduling problem that involves regular and emergency patients in parallel OT for a single day is considered in this study. Parallel OT is described as multiple OT that are unrelated to each other and all of the OT are operated simultaneously. Other

than that, the OT that are considered in this research is the general OT. In order to address the patient scheduling problem, a few algorithms are developed in this study to systematically schedule patients in the OT.

1.2 Problem Statement

The problems regarding scheduling in OT involving emergency patients have been considered as complicated challenges by many authors. In this study, the patient scheduling problem in parallel OT using three different types of local search (LS) which are LS, improved local search (ILS) and mixed local search (MLS) are studied. Some of the issues about the patient scheduling problem are:

1. What are the effects on the OT and the patients when considering patient scheduling problem?

2. How to schedule the emergency patients while minimizing the cost usage of the OT?

3. How does the different methods used in the initial solution give impact on the patient scheduling problem?

1.3 Objectives

The main objective of this study is to develop different types of LS for solving patient scheduling problem. The list below presents the specific objectives of this study:

1. To develop low-level heuristic for the improvement of patient scheduling problem solution.

2. To design algorithms for initial schedule and the parallel OT scheduling process.

3. To test the algorithms by generating a variety of patients data and solve the problem with aims of minimizing the cost of OT overtime and delayed patients.

1.4 Scope and Limitations

The scope of this study is to schedule regular and emergency patients in parallel OT for a single day, and focusing on local search method in order to achieve better results. Solving for patient scheduling problem that considers emergency patients is a challenging task. Below are the several limitations in this research:

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- The problem in this research is to schedule emergency patients on the day. In reality, there are a few types of emergency cases. For example, some emergency patients' cases need to be operated on instantly, due to their life threatening conditions. In this study, emergency patients that still can wait before going through with the operation as soon as the OT is available are considered, but need to be operated on the day of arrival.

- This research focuses on scheduling of patients on that one day only so that all the prioritized patients could complete the operations efficiently. During the scheduling process, some of the patients may have to be delayed to another day in order to minimize the cost which is the research objective. In this research, the cases after delaying the patients to another day schedules are not taken into account.

- For real problem of scheduling, there is a lot of constraints to be considered and it depends on the cases. But this research focuses on scheduling the patients into one of the OT and some of the patients may be untreated depending on the situations. Other than that, any overtime usage of the OT is considered in this research since it affects the cost of consumption.

1.5 Significance of the Study

Scheduling for patients in OT is a critical issue in the healthcare industry. This scheduling issue has the largest consumption as well as gives the largest contribution to the hospital. It is important that the management of a hospital to have an efficient schedule in order to provide the best services for the patients. Most importantly, the hospital needs to prioritize the emergency patients and schedule as fast as possible in the OT. Scheduling that involves emergency patients is a complicated problem for researchers to deal with since many aspects need to be considered when facing the problem. Hence, most literature focused more on scheduling for elective patients than emergency patients. For that reason, there is lack of research that considered the emergency patients as their uncertain arrival time leads to a challenging task in the scheduling.

Generally, there are various approaches for solving the patient scheduling problem and every method has its advantages and limitations. It depends on the diversity of issues and their characteristics. Heuristic approach is commonly used in literature as it is practical and easy to implement to obtain good solutions for the problem quickly. However, a complementary approach of heuristic and optimization such as local search can give more effective solutions in terms of quality and computational time. Therefore, in this study, scheduling for regular patients and also emergency patients in the OT by using local search are presented since it is important for the healthcare industry to provide efficient services and satisfaction for the patients. It could also enhance the chance of survival of the patients.

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1.6 Outline of Thesis

Chapter 1 comprise of research background, problem statement, objectives, scope and limitations, significance of the study and outline of the thesis. Literature review of previous studies that are related to this study are discussed in Chapter 2. Methodology used for solving the patient scheduling problem are explained in Chapter 3.

Meanwhile, Chapter 4, 5 and 6 introduce the different types of LS used in the problem such as LS, ILS and MLS respectively. The algorithms are discussed in detail in these chapters. The computational results and discussion for each method are also presented in these three chapters. Lastly, the overall conclusion from this study and some recommendations for future research are made in Chapter 7.

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PUBLICATIONS

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