PRIORITIZATION METHODOLOGY FOR A LARGE SCALE OF REMOTE PATIENTS: A CASE STUDY OF CHRONIC HEART DISEASE

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ABSTRACT

This research aims to present a methodology based on Multi-Criteria Decision Making (MCDM) to aid decision-makers in prioritizing a large scale of patients in a telemedicine environment. In this study, the data from 500 patients with chronic heart disease are examined and evaluated their emergency levels based on four main sources: electrocardiogram (ECG), oxygen saturation (SPO2), blood pressure (BP), and non-sensory measurement (text frame). The researcher of this study constructed a decision matrix based on a crossover of multiple sources and patients list according to the features of the sources. Subsequently, patients were prioritized using MCDM techniques, namely, integrated Multi-layer Analytic Hierarchy Process (MLAHP) and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). For validation, subjectively, cardiologists are consulted to confirm the ranking results; objectively, mean ± standard deviation and T-test are used to check the accuracy of the systematic ranking. For evaluation, this study provided scenarios and checklist benchmarking to evaluate the proposed and existing prioritization methods. The following results were obtained. (1) Integrating MLAHP and Group-TOPSIS is effective for solving patient prioritization problems. (2) In subjective validation, the first five patients assigned to the doctors are the most critical cases needing the highest priority levels, whereas the last five are the least critical cases and thus given the lowest priority levels. In objective validation, significant differences were observed between the groups' scores, indicating that the ranking results were identical. (3) In evaluation, regarding the first, second, and third scenarios, the proposed method had an advantage over the benchmark method with rates of 40%, 60%, and 100%, respectively. The implications of this study, will gain the benefits to medical organizations in provide a way to improve the priority settings processes for the healthcare manages constantly making difficult resource decisions. As well as benefits to doctors by assist medical teams through providing a decision making support for prioritizing and perform a timely and accurate treatment of their patients. Moreover, the benefits to patients are provided as the prioritization improves fairness, decreases urgent waiting times for patients with heart chronic disease.

KAEDAH PENGUTAMAAN BAGI PESAKIT PENDUDUK PEDALAMAN BERSKALA BESAR: KAJIAN KES BAGI PENYAKIT JANTUNG KRONIK

ABSTRAK

Kajian ini bertujuan untuk membentangkan rangka kerja berdasarkan *Multi-Criteria Decision Making (MCDM)* bagi membantu pembuat keputusan mengutamakan pesakit berskala besar persekitaran tele-perubatan. Melalui kajian ini, data dari 500 pesakit jantung kronik yang telah diperiksa dan dinilai tahap kecemasan mereka berdasarkan empat ukuran utama iaitu *Electrokardiogram* (ECG), oksigen tepu (SPO2), tekanan darah dan pengukuran bukan deria (bingkai teks). Penyelidik kajian ini membina matriks keputusan berdasarkan pelbagai sumber bersilang dan senarai pesakit mengikut ciri-ciri sumber. Seterusnya, pesakit dinilai berdasarkan Teknik MCDM, iaitu *Integrated Multi-layer for Analytic Hierarchy Process (MLAHP)* dan *Technique for Order Performance by Similarity to Ideal Solution (TOPSIS)*. Bagi tujuan pengesahan pakar kardiologi telah dirujuk untuk mengesahkan keputusan kedudukan secara subjektif, sedangkan secara objektifnya, perhitungan min ± sisihan piawai dan ujian-T dalam memastikan kedudukan yang sistematik. Manakala bagi penilaian pula, pelbagai senario dan senarai tanda aras telah disediakan untuk menilai dan membandingkan kaedah sedia ada yang telah dicadangkan. Hasil kajian telah menghasilkan penemuan berikut: (1) Intergrasi TOPSIS dan MLAHP secara sistematik adalah berkesan untuk menyelesaikan penetapan pesakit terhadap permasalahan pengutamaan kritikal. (2) Dalam kesahan, secara subjektifnya lima pesakit pertama yang diberikan kepada Doktor menjadi kes yang paling terkini yang memerlukan tahap keutamaan yang paling tinggi, manakala pesakit yang lima terakhir pula menjadi tahap keutamaan yang paling rendah berbanding yang lain. Sedangkan secara objektifnya terdapat perbezaan yang ketara yang telah dikenal pasti di antara skor-skor kumpulan yang menunjukkan bahawa keputusan kedudukan adalah sama. (3) Mengikut penilaian senario pertama, kedua dan ketiga , kaedah yang telah dicadangkan mempunyai kelebihan terhadap kaedah penanda aras iaitu dengan peratusan masing-masing sebanyak 40%, 60% dan 100%. Kesan kajian ini, akan mendatangkan kebaikan kepada organisasi perubatan dalam menyediakan jalan penyelesaian bagi membaiki proses tetapan keutamaan untuk mengurus penjagaan kesihatan secara tetap terhadap sumber keputusan yang sukar. Di samping itu, kebaikan kepada Doktor daripada pasukan pembantu perubatan melalui penyediaan sokongan keputusan untuk keutamaan dan menjalankan rawatan pada waktunya dan tepat kepada pesakit-pesakit mereka. Tambahan pula, kebaikan kepada pesakit dengan menyediakan keutamaan membantu keadilan, mengurangkan masa menunggu kepada pesakit yang mengidap penyakit jantung kronik

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BFAWC	Back-Forward Adjustment for Weight Computing
BP	Blood Pressure
CESIRA	Coscienza, Emorragie, Shock, Insufficienza respiratoria, Rotture, Altro
DEEDS	Data Elements for Emergency Departments
DES	Discrete Event Simulation
DGP	Dynamic Grouping and Prioritization
DM	Decision Making
DSS	Decision Support System
ECG	Electrocardiogram
ED	Emergency Department
E-health	Electronic Health
EM	Evaluation Matrix
ESI	Emergency Severity Index
FCFS	First Come First Serve
FFMEA	Fuzzy Failure Modes and Effects Analysis

GDM	Group Decision Making
GSM	Global System for Mobile Communication
HAW	Hierarchical Adaptive Weighting
HOCA	Healthcare Aware Optimized Congestion
IMDs	Interoperable Medical Devices
IS	Information System
MAC	Media Access Control
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MCI	Mass Causalities Incidence
MEW	Multiplicative Exponential Weighting
MIs	Medical Institutes
MLAHP	Multi-layer Analytic Hierarchy Process
mmHg	Millimetres of Mercury
MTS	Manchester Triage System
NIS	Negative Ideal Solution
PC	Priority Code
PGS	Patient's Guidance System
PIS	Positive Ideal Solution
QOS	Quality of Service
RHMSs	Remote Health Monitoring Systems
SAW	Simple Additive Weighting
SpO2	Blood Oxygen Saturation Level

STM	Sacco Triage Method
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
WBAN	Wireless Body Area Network
WHO	World Health Organization
WPM	Weighted Product Method
WSM	Weighted Sum Model

APPENDICES LIST

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter introduces the research topic, problem statement, and research objectives. It also presents and explains the experimental and technical scopes of this research. Section 1.2 presents a brief background of the research components. Section 1.3 identifies and introduces the problem statement, on which the direction of the research is based. Section 1.4 follows with a description of the research objectives. Section 1.5 discusses the scope of the study. Section 1.6 briefly outlines the main structure of the thesis. Finally, Section 1.7 summarizes this chapter.

1.2 Research Background

The combined effect of increasing life expectancy and population aging will undoubtedly increase the societal burden of chronic illnesses among future populations of older people (Parekh, Goodman, Gordon, & Koh, 2011). The aging population and increasing number of chronic diseases have encouraged society to foster health consciousness among patients, encouraging them to become "health consumers" looking for improved health management (Touati & Tabish, 2013). Increase in the number of patients is expected to be driven by various causes, such as population aging, disasters, and mass casualty incidents (MCIs). One possible solution to these problems is for patients to be prioritized for services and treatments by triage nurses (Salman, Rasid, Saripan, & Subramaniam, 2014; Tebé et al., 2015). However, challenges to prioritization increase when patients are far from hospitals and use remote healthcare services (Salman et al., 2014).

A prioritization process is often conducted to ensure that care is given in an appropriate and timely manner (Seising & Tabacchi, 2013). Early identification of critically ill patients and stratification into priority levels upon admission to the emergency department (ED) is important for the quality and safety of emergency medicine (Acampora, Cook, Rashidi, & Vasilakos, 2013; Rocha et al., 2013). Therefore, the primary aim of patient prioritization is to identify patients who can safely wait and those who cannot (Brown & Clarke, 2014). Patient prioritization improves fairness and decreases the waiting times of urgent patients. The patients' condition should be the primary tool in assessing their priority according to medical guidelines (Polk, Walker, & Bhatia, 2007). In the hospital domain, prioritization has traditionally relied on the ability of nurses to assess cases (Christensen et al., 2011; Sakanushi et al., 2013; Zarabzadeh et al., 2013). Vital signs are very important in the prioritization setting because these provide an objective complement to the professional judgment of nurses and optimize inter-rater consistency (Westergren, Ferm, & Häggström, 2014).

For remote patients, who live far from hospitals and use tele-monitoring tools, continuous monitoring from a distant hospital is highly desirable to ensure adequate care and provide suitable guidelines for proper medication (Mirkovic, Bryhni, & Ruland, 2012). Remote patient care is now becoming a subject of major concern in healthcare services (Sarkar & Sinha, 2014). Remote prioritization, meanwhile, means triaging patients for treatment and transportation to hospitals after evaluating their vital signs (Sakanushi et al., 2013). Furthermore, prioritization is required to improve the processing of telemedicine patients (Salman et al., 2014) and the emergency operations in remote healthcare services and disaster systems. Remote home patients, especially the elderly, are at critical risk of harm during a disaster (Wyte-Lake, Claver, & Dobalian, 2016). Thus, prioritization processes are important to support the continuous care of remote patients in a pervasive environment. The overwhelming heterogeneous data can cause difficulty in deciding which patient out of many should be first provided with care (Sarkar & Sinha, 2014). Thus, decision-based methods for prioritizing patients in this environment are urgently needed (Sarkar & Sinha, 2014).

In view of the above discussion, emerging technology offers the potential for sensor networks and information combination to help health services with patient prioritization. For example, a patient with cardiovascular disease may use wearable or implanted biological sensors that monitor vital signs such as pulse rate and blood pressure (BP); when these vital signs are detected as unstable, the smart healthcare service notifies the user (Jentsch, Ramirez, Wood, & Elmasllari, 2013; Touati & Tabish, 2013).

Prioritization based on medical condition and chance of survival is complex (O. M. Ashour & Okudan, 2010b; Claudio & Okudan, 2010; Göransson, Ehnfors, Fonteyn, & Ehrenberg, 2008) because the decision is made based on a set of attributes (Faulin, Juan, Grasman, & Fry, 2012). Thus, several prioritization methods have been designed to achieve triaging goals and help triage nurses make accurate triage judgments for patients who are physically inside the ED (Christensen et al., 2011; Claudio, Kremer, Bravo-Llerena, & Freivalds, 2014; Pinto Júnior, Salgado, & Chianca, 2012; Sakanushi et al., 2013; Seising & Tabacchi, 2013). In addition, even though most triage systems categorize patients into a priority group, the order of patients is typically determined using the first come, first served (FCFS) principle. However, in the case of remote patients, neither triage doctors nor triage nurses are physically available to help them. Therefore, prioritizing is a complex, multi-attribute decision-making process, especially in a remote monitoring environment. This process raises questions such as how remote patients can be prioritized. These concerns, which are directly related to patients' lives, are our research problems. This study aims to improve the efficiency of large-scale remote patient prioritizing processes.

1.3 Research Problem

Patient prioritization employing medical conditions and chance of survival is considered a complex decision-making problem (O. M. Ashour & Okudan, 2010b; Claudio & Okudan, 2010; Göransson et al., 2008; Seising & Tabacchi, 2013). For large numbers of critically ill or injured patients, prioritizing of the patients is required (Alemdar & Ersoy, 2010; Azeredo, Guedes, de Almeida, Chianca, & Martins, 2015).

However, scalability becomes a challenge when the expected number of patients increases for various reasons, such as population aging, disasters, and MCIs (Salman et al., 2014). In existing systems, patients who are physically present at the ED of a hospital are prioritized by triage nurses and rely on the prioritizing skills of nurses (Azeredo et al., 2015). In an ideal world, patients in an ED would be provided with care on an FCFS basis (Claudio & Okudan, 2010). However, in reality, FCFS cannot be applied. Hence, a quick, well-informed, and timely decision on prioritizing patients is needed (Claudio & Okudan, 2010; K. W. Tan, 2013). If made appropriately, such decisions can save lives, among other advantages. Prioritization also becomes complicated when patients are far from the hospital (remote patients) and rely on telemedicine. In this case, triage nurses and doctors are not physically available to help the patient. Situations that utilize telemedicine are more complex than those in actual ED situations (Rasid, Fadlee, Saripan, K Subramaniam, & Salman, 2013; Salman et al., 2014) as a remote healthcare systems.

Remote healthcare systems in telemedicine have gained considerable attention because of their significant role in the lives of people (Salman et al., 2014; Sanders, Devergnas, Wichmann, & Clements, 2013). In telemedicine, patients are prioritized for treatment and transportation to hospitals on the basis of their vital signs (Sakanushi et al., 2013; Salman et al., 2014). Thus, prioritizing remote patients involves simultaneous consideration of multiple attributes (vital signs and complaints) with respect to assigning the proper weight for each attribute to determine the patients requiring the most urgent care (Faulin et al., 2012; Sakanushi et al., 2013). In more details; for patients who have the most emergency cases should receive the highest priority level, while the patients who have the less emergency cases should be given the lowest priority levels compared to other patients' scores over telemedicine environment. However, setting this prioritization is a very difficult and challenging task as it involves simultaneous consideration of heterogeneous data from multiple attributes for evaluation vital signs and text and generates data conflict. For example, ECG and SpO2 have been proven to be very important in prioritization setting because they provide an objective complement to optimize inter-rater consistency. Furthermore, each decision maker gives different weights for these attributes (vital signs). On one hand, a server who aims to give a score for a patient might give more weight to the vital feature rather than to others features that gain less interest. Thus, the prioritization processes as large scales of remote patients with chronic heart diseases in particular is a multi-complex attributes problem, where each patient is considered as an available alternative for the decision maker. Figure 1.1 illustrates the problem statement configuration.