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NOVEL TECHNIQUE FOR REORGANISATION OF OPINION ORDER TO INTERVAL LEVELS FOR SOLVING SEVERAL INSTANCES REPRESENTING PRIORITISATION IN PATIENTS WITH MULTIPLE CHRONIC DISEASES

KHALID IBRAHIM MOHAMMED ALGBURI

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DR. AWS ALAA ZAIDAN
Department of Computing
Faculty of Art, Computing and Creative Industry
Sultan Idris Education University

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Alhamdulillah, first and foremost, praise be Allah, the Cherisher and Sustainer of the World and to the Prophet Muhammad (Peace and Blessings of Allah Be upon Him) who was sent by Allah to be a great teacher to the mankind.

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ABSTRACT

Telemedicine has been increasingly used in healthcare to provide services to patients remotely. However, prioritizing patients with multiple chronic diseases (MCDs) in the telemedicine environment is challenging due to the complexity of decision-making based on the different degrees of emergency of such patients. As such, this study was carried out to propose a novel technique called Technique for Reorganization of Opinion Order to Interval Levels (TROOIL) to prioritize patients with MCDs in real-time using a remote health-monitoring system. The proposed TROOIL technique comprises six steps for prioritizing MCD patients, namely the conversion of actual data into intervals, generation rule, ordering rule, expert-rule validation, data reorganization, criteria weighting, and ranking alternatives for each rule. A secondary dataset of 500 remote patients with three chronic diseases, namely chronic heart disease, high blood pressure, and low blood pressure, was adopted from the most relevant prioritization study. The findings showed that the proposed TROOIL was able to prioritize MCD patients effectively, as those with a high degree of emergency were given top priority. For the objective validation, the comparison indicated that the first group's scores were the highest for all rules, indicating that the ranking results were identical. For the evaluation of all scenarios, the performance of the proposed technique exceeded that of the benchmark by 22.95%. In conclusion, the proposed TROOIL technique can effectively deal with multiple decision-making problems in prioritizing MCD patients. As such, this novel technique can be used to help healthcare centers to provide prompt services to MCD patients based on their level of priority, to assist medical organizations to improve the priority setting processes, and to provide medical doctors with decision-making support in prioritizing their patients for timely and accurate treatments.

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KAEDAH BARU PENYUSUNAN SEMULA ARAHAN PENDAPAT KEPADA ARAS SELAAN UNTUK MENENTUKAN KEUTAMAAN PESAKIT KRONIK

ABSTRAK

Teleperubatan semakin digunakan dalam penjagaan kesihatan untuk menyediakan perkhidmatan kepada pesakit secara jauh. Namun, menentukan keutamaan pesakit dengan penyakit kronik dalam persekitaran teleperubatan ada mencabar disebabkan kerumitan dalam membuat keputusan berdasarkan darjah kecemasan para pesakit berkenaan. Oleh yang demikian, kajian ini dijalankan untuk memperkenalkan satu teknik baru yang dinamakan Technique for Reorganization of Opinion Order to Interval Levels (TROOIL) yang boleh digunakan untuk menentukan keutamaan pesakit-pesakit kronik dalam masa nyata dengan menggunakan sistem pemantauan jauh. Teknik TROOIL yang dicadangkan mempunyai enam langkah untuk menentukan keutamaan pesakit kronik, iaitu penukaran data sebenar kepada data selaan, peraturan penjanaan, peraturan penyusunan, pengesahan pakar, organisasi semula data, kriteria pemberatan, dan pemeringkatan alternatif bagi setiap peraturan. Satu set data sekunder terdiri daripada 500 pesakit yang mempunyai penyakit kronik, iaitu penyakit jantung, tekanan darah tinggi, dan tekanan darah rendah, diadaptasikan dari sebuah kajian penentuan keutamaan yang terkini. Dapatan menunjukkan teknik TROOIL yang dicadangkan dapat menentukan keutamaan pesakit kronik dengan berkesan di mana mereka yang mempunyai darjah kecemasan yang tinggi diberikan keutamaan yang tinggi. Bagi pengesahan objektif, perbandingan menunjukkan skor kumpulan pertama adalah tertinggi untuk semua peraturan, dan ini memperlihatkan kesemua keputusan pemeringkatan adalah sama. Bagi penilaian dalam semua senario, prestasi teknik TROOIL adalah melebihi prestasi penanda aras sebanyak 22.95%. Sebagai kesimpulan, teknik TROOIL yang dicadangkan boleh digunakan untuk menangani masalah dalam membuat pelbagai keputusan yang berkaitan dengan penentuan keutamaan pesakit kronik. Oleh yang demikian, teknik baru ini boleh digunakan untuk membantu pusat penjagaan kesihatan dalam menyediakan perkhidmatan yang pantas kepada pesakit kronik berdasarkan tahap keutamaan mereka, membantu organisasi perubatan dalam memperbaiki proses penentuan keutamaan, dan menyediakan sokongan kepada doktor perubatan dalam menentukan tahap keutamaan pesakit mereka bagi mendapatkan rawatan yang cepat dan tepat.

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TABLE OF CONTENTS

DECLARATION OF ORIGINAL WORK ii
DECLARATION OF THESIS iii
ACKNOWLEDGMENT iv
ABSTRACT v
ABSTRAK vi
TABLE OF CONTENTS vii
LIST OF TABLES x
LIST OF FIGURES xi
LIST OF ABBREVIATIONS xii
LIST OF APPENDICES xii
CHAPTER 1 INTRODUCTION 1
1.1 Introduction 1
1.2 Research Background 2
1.3 Research Problem 5
1.4 Research Qustiones 11
1.5 Research Objectives 12
1.6 Connections among Research Objectives, and Research Questions 12
1.7 Research Scope 13
1.8 Significant of the Study 15
1.8.1 Benefits to Patients 16
1.8.2 Benefits to Medical Organizations 17
1.8.3 Benefits to Physicians 17
1.9 Research Organisation 18
1.10 Chapter Summary 20
CHAPTER 2 LITERATURE REVIEW 21
2.1 Introduction 21
2.2 Systematic Review Protocol 24
2.2.1 Method 24
2.2.2 Information Sources 24
2.2.3 Study Selection 25

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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2.2.4 Search 25
2.2.5 Eligibility Criteria 26
2.2.6 Taxonomy Analysis 27
2.3 Telemedicine Applications: An Overview 30
2.4 Sensor Based (Tier 1): An Overview 32
2.5 Gateway Based (Tier 2): An Overview 36
2.6 Server Based (Tier 3): An Overview 40
2.6.1 Remote Monitring (Telemonitoring) 42
2.6.2 Healthcare Service Concerns in Telemedicine 45
2.6.3 Critical Review and Analysis 51
2.7 MCDs in RHM 53
2.7.1 CHD 54
2.7.2 Chronic BP Disease 55
2.8 Sources Used to Measure Patients' Medical Vital Signs 57
2.9 Triage System Standards and Guideline 60
2.10 Concern for Prioritisation Process 66
2.11 MCDM: An Overview 67
2.11.1 MCDM: Definition and Importance 68
2.11.2 MCDM Techniques and Methods 69
2.12 Chapter Summary 76
CHAPTER 3 RESEARCH METHODOLOGY 77
3.1 Introduction 77
3.2 Phase I: Preliminary Study 80
3.3 Phase II: Decision Technique 80
3.4 Phase III: Prioritisation of Patients with MCDs 86
3.4.1 Targeted Tier within the Telemedicine Architecture 87
3.4.2 Patients Dataset 88
3.4.3 Converting Actual Data into Triage Patients with MCDs 89
3.4.4 Rule Generation, Ordering and Validation for MCDs 93
3.4.5 Matching in between Triage Patient Level and RuleValidation 94
3.4.6 Prioritisation of Patients within Each Rule 95
3.5 Phase VI: Validation and Evaluation 96

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

3.5.1 Validation Process 96
3.5.2 Evaluation Process 98
3.6 Chapter Summary 100
CHAPTER 4 RESULTS AND DISCUSSION 101
4.1 Introduction 101
4.2 Dataset Result of Patients with MCDs 103
4.3 TROOIL Result of Prioritisation of Patients with MCDs 104
4.3.1 Result of Converting Actual Data into Triage Patients with MCDs 105
4.3.2 Result of Rule Generation, Ordering and Validation 107
4.3.3 Result Of Matching Process Between Triage Level And Validated Rules 111
4.3.4 Criteria Weighting And Patient Prioritisation Within Each Rule 113
4.4 Chapter Summary 119
CHAPTER 5 VALIDATION AND EVALUATION 120
5.1 Introduction 120
5.2 Validation Process 121
5.3 Evaluation Process 125
5.4 Chapter Summary 137
CHAPTER 6 CONCLUSION AND FUTURE WORK 139
6.1 Introduction 139
6.2 Research Goals Attained 140
6.3 Research Contributions 142
6.4 Research Limitations 144
6.5 Recommendations for Future Work 144
REFERENCES 146
LIST OF PUBLICATIONS 171
APPENDICES 172

05-4506832 pustaka.upsi.edu.my Perpustakaan Tuanku Bainun Kampus Sultan Abdul Jalil Shah PustakaTBainun ptbupsi

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LIST OF TABLES

Table. No		Page
1.1	Connection amongst Research Objectives and Research Questions	13
2.1	Description of Relevant Medical Sources Used in Monitoring Patients	58
2.2	Classification of Emergency BP levels	59
2.3	State-of-the-Art Triage Systems	61
3.1	Triage Levels for CHD-based MSHA	90
3.2	Triage Levels for High and Low BP-based Medical Guidelines	91
3.3	Decision Matrix	95
4.1	Sample of the Dataset Presentation Results	103
4.2	Sample of the Result Triage Level	106
4.3	Sample of the Results Data Alignment Process for Triage Levels	107
4.4	Rule Generation and Ordering Dynamically	108
4.5	Rule Ranking based on Medical Committee Perspectives	110
4.6	Sample Result of Matching between Patient Triage and Validated Rules	112
4.7	Decision Matrix for Patients within Rule 1	113
4.8	Normalised Decision Matrix for Patients within Rule 1	115
4.9	Entropy Values and Weights for Each Criterion for Each Rule	116
4.10	Patient Prioritisation within Rule 1	117
5.1	Statistical Analysis Results for Patient Prioritisation within all Rules	124
5.2	Checklist Benchmarking	133
5.3	Comparison Scenarios and their Related Issues	135
6.1	Connections among Objectives, Justification and Methodology	141

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LIST OF FIGURES

Figure. No		Page
1.1	Problem Statement Configurations	10
1.2	General Scheme and Scope of the Study	15
1.3	Significant Categories of the Study	16
2.1	Literature Review Structure	23
2.2	Study Selection Flowchart Contains the Exact Query and Inclusion Criteria	27
2.3	Research Taxonomy on Telemedicine Applications	29
2.4	Three-Tiered Architecture for Healthcare Monitoring	31
2.5	Taxonomy of Healthcare Service Challenges	46
2.6	Problems that Cause the Increase in Users' Request in RHMSs	47
2.7	National Healthcare Expenditure Per Capita in the USA	49
3.1	Research Methodology Phases	79
3.2	High-Level Abstract of the Telemedicine Architecture	88
3.3	Validation Processes	98
4.1	Overview of Results and Evaluation of Prioritising Patients with MCDs	102
5.1	Structure of the Validation Processes	122
5.2	Relationship between the Comparison Issues and Scenarios	128
6.1	Research Contributions and Novelty Mapping	143

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LIST OF ABBREVIATIONS

AAL	Ambient Assisted Live
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
BP	Blood Pressure
BWM	Best-Worst Method
CHD	Chronic Heart Disease
CHDs	Chronic Heart Diseases
DM	Decision Making
ECG	Electrocardiogram
ED	Emergency Department
e-health	Electronic Health
E-health	Electronic Health
EHRs	Electronic Health Records
EMI	Electromagnetic Interference
EMI	Electromagnetic interference
FAD	False Alarm Detection
FCFS	First Come First Serve'
HAW	Hierarchical Adaptive Weighting
IMDs	Interoperable Medical Devices
IoT	Internet-of-Things
KSFs	Key Success Factors
MAC	Media Access Control
MAIRCA	Multi-Attribute Ideal-Real Comparative Analysis
MBAN	Medical Body Area Network
MCDA	Multiple-Criteria Decision Analysis
MCDM	Multiple-Criteria Decision-Making
MCDs	Multiple Chronic Diseases

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MCIs	Mass Casualty Incidences
MEW	Multiplicative Exponential Weighting
mHealth	Mobile Health
MSHA	Multi Source Health Architecture
MTS	Manchester Triage System
MUI	Mobile User Interface
NIS	Negative Ideal Solution
PHRs	Personal Health Records
PIS	Positive Ideal Solution
QOS	Quality of Service
RHM	Remote Health Monitoring
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
TROOIL	Technique for Reorganising Opinion Order to Interval Levels
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje
WBANs	Wireless Body Area Networks
WHO	World Health Organization
WPM	Weighted Product Method
WSM	Weighted Sum Model

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LIST OF APPENDICES

A	Medical Committee & List Of Experts
B	Dataset Presentation Results
C	The Overall Triage Level Results
D	The Overall Matching Process
E	Decision Matrix For Patients Within Eage Rule
F	Patient Prioritisation Within Within Eage Rule

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CHAPTER 1

INTRODUCTION

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1.1 Introduction

This chapter introduces the research topic, statement of the problem and research objectives. It also presents the scope of this research where the experimental and technical scopes are explained. A brief background of the research components is presented in Section 1.2. The statement of the problem, on which the direction of the research is based, is identified and introduced in Section 1.3. Research questions are listed in Section 1.4, followed by the objectives of the research described in Section 1.5. The connections among research objectives and research questions are presented in Section 1.6. Furthermore, the scope of the study is discussed in Section 1.7.

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The significance of the study is presented in Section 1.8, followed by the main structure of the thesis in Section 1.9. Finally, a summary of the chapter is presented in Section 1.10.

1.2 Research Background

Telemedicine used in healthcare has been growing rapidly because it offers remote healthcare services to patients in distant locations (Rogove, McArthur, Demaerschalk, & Vespa, 2012; Topol, 2015). Telemedicine is a remote medical practice in which different healthcare providers cooperate and permit their collaborative efforts in the diagnosis or treatment of a disease (M. B. Doumbouya, Kamsu-Foguem, Kenfack, & Foguem, 2015). The goal of telemedicine is to provide medical services at remote areas through telecommunication technologies (Moghadas, Jamshidi, & Shaderam, 2008). Remote healthcare services can be beneficial to patients living in isolated communities and far-flung regions, given that they can receive professional care from physicians or specialists who travel to visit them (Gilpin & Gilpin, 2000).

Triage in telemedicine is the concept of sorting patients in order of treatment necessity in a large-scale emergency. In other words, it is the process of assessing and prioritising care for all patients and casualties (O. H. Salman, Rasid, Saripan, & Subramaniam, 2014). A prioritisation process is often conducted to ensure that care is given in a suitable and timely method (Seising & Tabacchi, 2013). Early identification of critically ill patients and stratification into priority levels upon acceptance to the

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emergency department (ED) are necessary for the quality and integrity of emergency medicine (Acampora, Cook, Rashidi, & Vasilakos, 2013; Rocha, Martins, Freire, et al., 2013). Hence, patient prioritisation aims to identify patients who can safely wait and those who cannot (Brown & Clarke, 2014). Patient prioritisation improves fairness and decreases urgent patients' waiting times. In addition, it can affect the distinctions among areas because it efficiently appropriates available resources within each region (Román et al., 2008; Tebé et al., 2015). Patients' case must be the main tool in assessing their priority according to medical guidelines (Polk, Walker, & Bhatia, 2007).

The common impact of increasing life expectancy and population old age will certainly be the increase in the societal burden of chronic diseases among future older populations (Parekh, Goodman, Gordon, & Koh, 2011). The aging population and the increase in the number of chronic diseases have encouraged society to foster health awareness among patients, emboldening them to become 'health consumers' looking for an enhanced health administration (Touati & Tabish, 2013). The increase in the number of patients is predicted to be driven by different reasons, particularly aging population, disasters and mass casualty incidences (MCIs). Moreover, these challenges increase when patients are far from hospitals and utilise remote healthcare services (O. H. Salman et al., 2014). One possible solution to these problems is that patients need to be prioritised remotely to acquire services and treatments by effective healthcare systems (O. H. Salman et al., 2014; Tebé et al., 2015).

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Different prioritisation methods have been designed to prioritise patients with chronic heart disease (CHD) living in remote regions. The previously proposed prioritisation solution can address prioritisation in patients with single chronic disease only. Furthermore, multi source healthcare architecture (MSHA) enhances efficiency of healthcare scalability by assisting remote prioritisation and triaging patients with CHDs (O. H. Salman et al., 2014). The patients are prioritised using a priority code (PC) with a range of 0–100. Only patients who are part of this range can be prioritised. Meanwhile, those with the same PC value were sorted in a descending order by applying the 'first come, first serve' (FCFS) approach. Moreover, a new approach based on multiple-criteria decision-making (MCDM) techniques was presented to prioritise large-scale data of patients with CHDs by using body sensors during disasters and peak seasons (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018).

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However, to our knowledge, an exclusive presentation of solution for remote prioritisation in a large scale of patients with multiple chronic diseases (MCDs), especially with the application of telemedicine, has not yet been reported (Tier 3).

Remote healthcare prioritisation systems have gained considerable attention because of their significant role in the lives of people (Omar H Salman, Rasid, Saripan, & Subramaniam, 2014; Sanders, Devergnas, Wichmann, & Clements, 2013). Remote prioritisation means triaging patients and identifying their priority for the treatment and transportation to hospitals after evaluating the patients' vital signs (Sakanushi et al., 2013). For remote patients, continuous monitoring from a distant

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hospital is highly desirable to ensure adequate care and provide suitable guidelines for proper medication (Mirkovic, Bryhni, & Ruland, 2012). Moreover, remote patient care is currently becoming a major concern in healthcare services (Sarkar & Sinha, 2014). Patients with multiple chronic conditions (e.g. CHD, chronic blood pressure [BP] disease, fall detection and diabetes) are at great risk of experiencing poor daily functioning (Kalid et al., 2018). MCDs contribute to frailty and disability. Functional limitations often complicate access to healthcare, interfere with self-management and necessitate reliance on caregivers (Services, 2010). Remote home patients, especially the elderly with MCDs, are at critical risk of harm in various situations (Kalid, Zaidan, Zaidan, Salman, Hashim, & Muzammil, 2018). Thus, prioritisation processes for MCDs are important to support the continuous care of remote patients in a pervasive environment.

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1.3 Research Problem

Scalability is the ability of a healthcare application to expand to meet the increased demands by users. Scalability issue arises when the number of patients expectedly increases in several aspects, such as population aging, disasters and MCIs (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018; Omar H Salman et al., 2014; Sangjin Jeong et al., 2012; Van Dyk, 2014). Scalability issues can cause an increase in the number of users, implying a huge problem in a medical centre (Kalid et al., 2018; Omar H Salman et al., 2014).

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In a large number of critically ill or injured patients, patients' prioritisation, which needs to be measured or evaluated, is an important yet difficult task (Alemdar & Ersoy, 2010; Azeredo, Guedes, Rebelo de Almeida, Chianca, & Martins, 2015). Patients' prioritisation employs medical conditions and the chance of survival, thereby indicating the chief problem (Ashour & Okudan, 2010; D Claudio & Okudan, 2010; Göransson, Ehnfors, Fonteyn, & Ehrenberg, 2008; Seising & Tabacchi, 2013). Prioritisations become complicated when patients are residing far from the hospital and use telemedicine; hence, triage nurses and physicians are not physically available to help such patients. This circumstance is more complex in telemedicine than in actual ED situations (O. H. Salman et al., 2014).

In the existing prioritisation studies, patients who are physically present at the ED of a hospital are prioritised by triage nurses and relied on the prioritising skills of nurses (Azeredo et al., 2015). Ideally, patients in an ED would be provided with care on an FCFS basis (D Claudio & Okudan, 2010). However, in reality, FCFS cannot be applied; hence, a quick, well-informed and timely decision on prioritising the patients is needed (D Claudio & Okudan, 2010; Tan, Tan, & Kauffman, 2013). Moreover, the proposed prioritisation solution in the previous studies (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018; O. H. Salman et al., 2014) can only address prioritisation in patients with single chronic disease; such approach cannot determine the emergency degree of each chronic disease in patients with MCDs to perform accurate prioritisation. However, no studies exist that can present a solution for remote prioritisation of patients with MCDs in a large scale, especially in the medical

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centre server of telemedicine applications (Tier 3). Such issue, if handled and addressed well, can save lives, among other advantages.

Furthermore, the prioritisation process for patients with MCDs requires decision making (DM) for each disease (i.e. CHD, high BP and low BP). This issue is considered as a specific problem of this research, considering that each patient should have a multigroup triage of different diseases for evaluating their emergency cases. This issue can be extended from a different side; decision makers (doctors) may give different weights for the mentioned diseases and multisource for each disease, thereby increasing the complexity of the task. Moreover, multigroup triage levels vary in each patient according to emergency cases. For instance, data variation of multigroup triage for each patient occurs when patient A has a risk level for heart disease, urgent level for high BP and normal level for low BP; meanwhile, patient B has an urgent level for heart disease, normal level for high BP and risk level for low BP. Hence, patient prioritisation is indeed a difficult task. Patient A can be prioritised at the highest level on the basis of heart disease (first disease). In contrast, patient B can also be prioritised at the highest level on the basis of low BP (third disease). In such case, a confusing question arises, that is, which patient will be prioritised first? Therefore, the prioritisation procedure that targets to assign a priority for a patient with MCDs includes simultaneous consideration of the emergency cases from MCDs. Thus, the prioritisation process of patients with MCDs involves multiple complex decision-making problems that represent an emergency degree in each chronic disease of these patients. Hence, a multiple-criteria decision analysis (MCDA) as the main concept to deal with this complicated situation is necessary.

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Based on the academic literature of MCDM techniques, the benefit of ranking approaches is appropriate for situations with many alternatives and attributes (Jumaah et al., 2017; Rahmatullah, Zaidan, Mohamed, & Sali, 2017; Zaidan et al., 2019). These methods have the capability to find the best alternative rapidly, and these techniques are considered the best among others. The mentioned methods are also specifically convenient to use when quantitative or objective data are given. These methods are functionally related to discrete-alternative problems. However, the major drawbacks of these ranking approaches include the lack of provision to weight elicitation and the consistency of judgments. In order to avoid this limitations, the literature review studies used external weighting techniques to improve the performance of the original ranking approaches through producing the importance of several criteria with respect to the objective; weighting approaches provide such a procedure (Alsalem et al., 2018; A. A. Zaidan et al., 2018). Furthermore, the benefit of other weighting techniques in both subjective and objective approaches can provide different weights for the adopted criteria to increase the performance of the DM process effectively. However, these techniques cannot be used to rank the available alternative individually. The explanation above applies to all MCDM techniques, except AHP. As shown in the literature, AHP technique was used for two directions, ranking and weighting purposes (O. S. Albahri, Albahri, et al., 2019). AHP was utilised to provide weights for criteria according to the preferences of experts and is remarkably restricted by the capacity of humans for processing information. However, AHP has an incredible drawback if used in the ranking purpose, which is inconvenient to use when dynamic data are provided in the DM process. This method is only used

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when static data are provided in the decision matrix. However, all existing ranking techniques, including AHP, cannot determine and break the decision into sub-decisions to guarantee the accuracy of the prioritisation process and determine the accurate emergency degree for patients with MCDs that represents multiple-DM problem (Mohammed et al., 2019), which is considered a technical gap. Although VIKOR technique produces balance between the overall utility and minimises the regret level (A. S. Albahri, Zaidan, Albahri, Zaidan, & Alsalem, 2018), assigning high priority for patient *n* more than patient *m*, in case of patient *n* is more risky when compared to patient *m*. These concerns, which are directly related to patients' lives, are our research problems. The problem statement configuration is illustrated in Figure 1.1.

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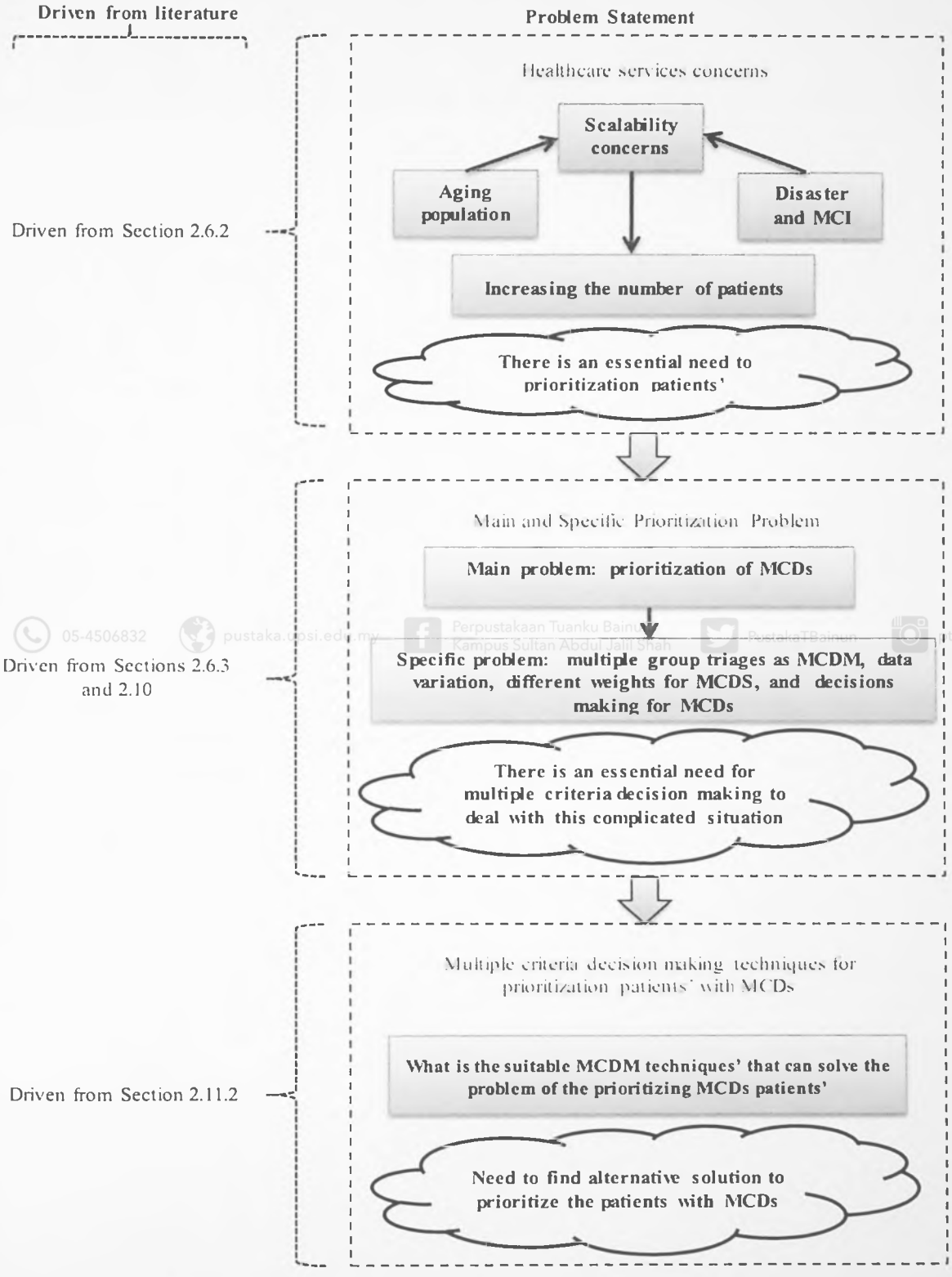


Figure 1.1. Problem Statement Configurations

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1.4 Research Qustiones

The following research questions have been framed to set the directions for this research:

1- What are the available technologies for patient prioritisation?
2- What are the requirements needed to construct a prioritisation technique for patients with MCDs in the telemedicine environment?
3- What is the suitable technique that can solve the problem of prioritising patients with MCDs in telemedicine?
4- Can the existing MCDM techniques be used to prioritise patients with MCDs?
5- How can patients with MCDs be prioritised on the basis of the proposed decision technique?
6- Is the proposed prioritisation technique for such patients valid systematically?
7- Is the performance of the proposed patient prioritisation technique better than those of other related techniques?

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1.5 Research Objectives

The objectives of this research are listed as follows:

1- To investigate the existing technologies of patient prioritisation in telemedicine applications and highlight their weaknesses.
2- To propose a new decision technique that deals with multiple decision-making for patients with MCDs.
3- To prioritise patients with MCDs on the basis of the proposed decision technique.
4- To validate and evaluate the proposed prioritisation of MCDs.

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1.6 Connections among Research Objectives, and Research Questions

In this section, all research questions can be answered through the research objectives. Each objective is linked to one or two questions. Table 1.1 below presents the connection among research objectives and the research questions.

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Table 1.1

Connection amongst Research Objectives and Research Questions

Research objectives	Research questions
1. To investigate the existing technologies of patient prioritisation in telemedicine applications and highlight their weaknesses.	1. What are the available technologies for patient prioritisation? 2. What are the requirements needed to construct a prioritisation technique for patients with MCDs in the telemedicine environment?
2. To propose a new decision technique that deals with multiple decision-making for patients with MCDs.	3. What is the suitable technique that can solve the problem of prioritising patients with MCDs in telemedicine? 4. Can the existing MCDM techniques be used to prioritise patients with MCDs?
3. To prioritise patients with MCDs on the basis of the proposed decision technique.	4. How can patients with MCDs be prioritised on the basis of the proposed decision technique?
5. To validate and evaluate the proposed prioritisation of MCDs.	5. Is the proposed patient prioritisation technique valid systematically? 6. Is the performance of the proposed patient prioritisation technique better than those of other techniques?

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As shown in Table 1.1, the first objective corresponds to the first and second question, the second objective corresponds to the third and fourth question, the third objective corresponds to the fifth question, and the last objective corresponds to the sixth and seventh question.

1.7 Research Scope

This research is a cross domain involving healthcare services and expert system algorithms. It is designed to solve the problem of remote patients' prioritisation for telemedicine environment. Different research methods are involved in the study

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because the problem is classified to be multidisciplinary. In this study, MCDs are involved in the experiments; thus, the settings and parameters of the multigroup triage used in the prioritisation process are adjusted.

The secondary dataset of 500 patients from the most relevant study in the remote prioritisation area is adopted (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018). This dataset contains three diseases (i.e. CHD, high BP and low BP), which are presented in two parts. The first part is the CHD. Sensors (e.g. electrocardiogram [ECG], oxygen saturation [SPO2] and BP) and texts were used as patients' vital signs to be assessed by healthcare providers. The second part includes the high and low BP diseases, which consist of sensors for systolic and diastolic pressures to be used as patients' vital signs for the healthcare providers to assess simultaneously with the first dataset (CHD).

The outcomes of the research indicate the research type. The output of this study is a new decision technique that can be used to improve the process of prioritising patients with MCDs for telemedicine.

Furthermore, the proposed technique for reorganising of opinion order to interval levels (TROOIL) represents the improvements in the performance of telemedicine applications from the perspective of MCDs. The general scheme for our research, as well as the research method, research type and research domain is presented in Figure 1.2.

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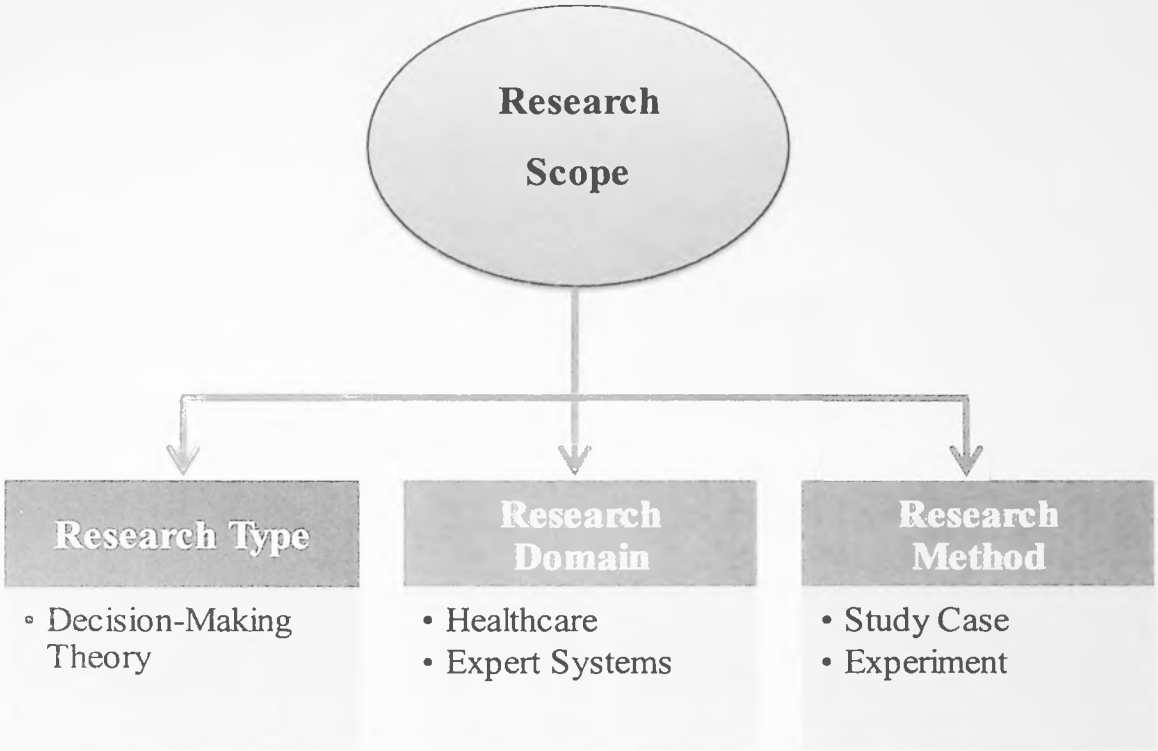


Figure 1.1. General Scheme and Scope of the Study

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1.8 Significant of the Study

The field of telemedicine has been developed rapidly because it offers obvious and compelling benefits. In this section, we present the benefits and significance of this research, which are organized into three categories according to related benefits. The corresponding significant is presented for further discussion (Figure 1.3).

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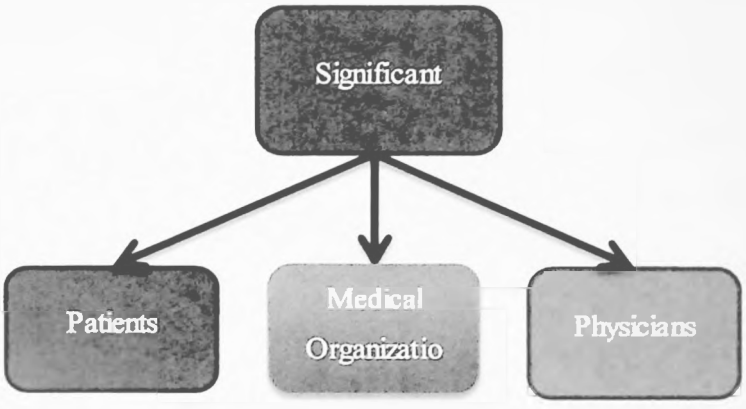


Figure 1.2. Significant Categories of the Study

1.8.1 Benefits to Patients

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EDs in hospitals are places where numerous people must be attended immediately and where critical situations are expected to emerge. When a patient arrives at the ED, he/she needs to be classified according to the seriousness of their conditions. A healthcare application remotely recognises patients with the most acute emergency cases; the patient with the most acute emergency case is the first to obtain a response from the server (Ganapathy, Vaidehi, Kannan, & Murugan, 2014; Hindia, Rahman, Ojukwu, Hanafi, & Fattouh, 2016; Moreno et al., 2016; Omar H Salman et al., 2014). A healthcare monitoring system can be used for health monitoring, particularly on elderly and persons with disabilities, and provide the patients with a service-oriented emergency response when they suffer abnormal health conditions (Hussain, Wenbi, da Silva, Nadher, & Mudhish, 2015; Peleg et al., 2017). Telemedicine services can effectively improve the quality of healthcare in large centres and deliver these

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services to unserved and underserved areas. A healthcare system can be used to recognise and decrease morbidity by providing health consultations in unreached areas (Rajkumar & Sriman Narayana Iyengar, 2013; Sakuragui, Rebelo, Gutierrez, Näslund, & Håkansson, 2013; Zanjal & Talmale, 2016). Finally, this research ensures continuous healthcare services to patients with MCDs by patient prioritisation among hospitals in cases of natural disasters or involving the aging population.

1.8.2 Benefits to Medical Organizations

Managing healthcare organisations is complex, owing to the dynamic operations and distribution of hospitals (Kalid et al., 2018). Thus, healthcare institutions must focus on this issue to adequately meet the requirements of patients (A. S. Albahri et al., 2018). Moreover, this research provides a way to improve the priority setting processes for healthcare providers who constantly make difficult resource decisions.

1.8.3 Benefits to Physicians

In a MCIs, the emphasis shifts from ensuring the best potential outcome for each individual patient to ensuring the best potential outcome for the greatest number of patients, helping medical teams acquire real-time information of multiple casualties for timely and accurate treatment and enabling rapid and optimal resource assignment according to the seriousness of the patients' status (Beck & Georgiou, 2016; Besaleva

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& Weaver, 2013; Niswar et al., 2013, 2015; Paulus et al., 2015; Renner et al., 2014; Rodriguez et al., 2014; Santos, Blard, Oliveira, & Carvalho, 2015; Ullah, Khelil, Sheikh, Felemban, & Bojan, 2013).

Tele-expertise can assist knowledge sharing and decision support among physicians across organisational and geographical boundaries. Such task is complex and important, and it is the core of the cooperation among telehealth, health professionals and medical professionals; this cooperation enables them to make suitable decisions for patient diagnosis or treatment and effectively manage the medical information of their patients (M. B. Doumbouya et al., 2015; Mamadou Bilo Doumbouya, Kamsu-Foguem, Kenfack, & Foguem, 2014; Sene, Kamsu-foguem, & Rumeau, 2015; Tegegne & (Theo) van der Weide, 2014; Urovi, Jimenez-del-Toro, Dubosson, Ruiz Torres, & Schumacher, 2017). Furthermore, tele-expertise can assist medical teams to gain real-time information of MCDs to perform a timely and accurate treatment of their patients, as can be demonstrated in this current research. Thus, this study is also essential for physicians.

1.9 Research Organisation

This research is composed of six chapters. These chapters are briefly reviewed as follow:

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Chapter 1 provides the research background and research problem. Moreover, this chapter demonstrates the research questions, objectives and the connection among research objectives and the research questions. This chapter also presents the research scope and significance of the study.

Chapter 2 presents a systematic review protocol for the area of telemedicine applications, followed by an overview of the following: sensor based (Tier 1), gateway based (Tier 2) and server based (Tier 3). MCDs in remote healthcare monitoring (RHM) were also reviewed, followed by the main medical sensors and sources involved in monitoring common chronic diseases. This chapter also examines and reviewed triage systems, standards and guidelines. Furthermore, the prioritisation process is addressed. This chapter ends with technical analyses to the research problems and highlights what should be accomplished to solve such problems.

Chapter 3 provides the full description of the research methodology, which consists of four phases, namely, preliminary study, decision technique, and prioritisation of patients with MCDs, validation and evaluation. Each phase corresponds and addresses to one research objective.

Chapter 4 presents the results based on the proposed work in several sections. Each section has its own aims. These sections show the result of the dataset of patients with MCDs; in this dataset, three diseases are used as input data in the proposed work.

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Chapter 5 presents the validation and evaluation results of the proposed work. In this chapter, several steps are involved in the validation and evaluation processes of the performance in patient prioritisation for telemedicine to overcome the research problems.

Chapter 6 presents the attained research goals, contribution, limitation and conclusion. The areas to be pursued as future works are also suggested in this chapter.

1.10 Chapter Summary

This chapter provides a background about the prioritisation process involving patients with MCDs and the remote monitoring over telemedicine. In the statement of the problem, the prioritisation process of such patients involves complex multiple-decision-making problems that represent the emergency degree of each chronic disease for each patient. This research mainly aims to improve the patient prioritisation; the specific objectives are also discussed. Research questions of this study are listed in this chapter. Moreover, the extent and constraints of this study are elaborated. Furthermore, this chapter presents the research benefits and significance, which are organised into three categories according to related benefits. The final part of this chapter presents the general idea of the other chapters in this thesis.

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