A NEW ALGORITHM FOR TRIAGE AND PRIORITIZATION PATIENTS IN TELEMEDICINE ENVIRONMENTAL

NOORSUZIYANTE BINTI MAT NAPI

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Department of Computing
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ABSTRACT

This research aimed to develop a new algorithm for triage and prioritisation for chronic heart disease patients in telemedicine environmental to aid decision-makers. In this study, the secondary data from 500 patients with chronic heart disease was derived from the most relevant remote triage and prioritisation studies and were evaluated in terms of their emergency levels based on four main sensor measurements: electrocardiogram (ECG), oxygen saturation (SpO2), blood pressure (BP), and text sensor. In this study, the patients were triaged as emergency patients and separated into five categories, which are risk, urgent, sick, cold state, and normal. Then, the patients were prioritised through the rank and order of the patients according to their emergency status. Subsequently, the patients were triaged using evidence theory that refers to four features of the ECG sensor, BP sensor, SpO2 sensor, and text sensor to determine the emergency level of the chronic heart disease patients. Then, they were prioritised using the integrated Multi-layer of Analytic Hierarchy Process (MLAHP) and the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). For validation, objectively, the mean deviation was used to check the accuracy of the systematic ranking. In terms of evaluation, this study has provided scenarios and benchmarking checklists to evaluate the proposed algorithm with the existing models. The results showed that: (1) the proposed triage and prioritisation algorithm was able to prioritise the patients effectively as those with a high degree of emergency were prioritised first. (2) For objective validation, the comparison indicated that the first group's score was the highest with a mean value of *0.013*, indicating that the prioritisation results were identical. (3) In the evaluation, regarding the scenarios, the proposed algorithm has an advantage over the benchmark works that cover either triage or prioritisation with percentage values of 34.3% and 50%, respectively. The implications of this study are able to identify the triage level and the ranking of a large scale of patients with chronic heart disease that could be used to provide services and treatments on the basis of emergency status. In conclusion, the main findings showed that this study will increase the performance of triage and prioritisation in the telemedicine environment.

ALGORITMA BARU UNTUK *TRIAGE* DAN PRIORITISASI PESAKIT DALAM PERSEKITARAN TELEPERUBATAN

ABSTRAK

Kajian ini bertujuan untuk membina algoritma baru untuk *triage* dan *prioritisation* bagi pesakit penyakit jantung kronik dalam persekitaran teleperubatan bagi membantu para pembuat keputusan. Dalam kajian ini, data sekunder daripada 500 pesakit yang menghidapi penyakit jantung kronik telah diperolehi daripada *triage* jauh yang paling relevan dan kajian *prioritisation* serta dinilai dari segi paras kecemasan berdasarkan empat ukuran sensor utama: elektrokardiogram (ECG), ketepuan oksigen (SpO2), tekanan darah (BP), dan sensor teks. Dalam kajian ini, para pesakit telah di *triage* sebagai pesakit kecemasan dan dipisahkan mengikut lima kategori iaitu berisiko, segera, sakit, keadaan sejuk, dan normal. Kemudian, para pesakit diberi keutamaan melalui kedudukan dan urutan mengikut status kecemasan mereka. Seterusnya, pesakit telah di *triage* menggunakan teori bukti yang merujuk kepada empat ciri sensor elektrokardiogram (ECG), sensor ketepuan oksigen (SpO2), sensor tekanan darah (BP), dan sensor teks bagi menentukan tahap kecemasan pesakit penyakit jantung kronik. Selepas itu, mereka diberi keutamaan melalui *Multi-layer of Analytic Hierarchy Process* (MLAHP) dan *Technique for Order Performance by Similarity to Ideal Solution* (TOPSIS). Bagi pengesahan secara objektif, min sisihan telah digunakan untuk memeriksa ketepatan kedudukan sistematik. Dari segi penilaian, kajian ini telah menyediakan senario dan senarai semak tanda aras untuk menilai algoritma yang dicadangkan dengan model yang sedia ada. Keputusan menunjukkan bahawa: (1) algoritma *triage* dan *prioritisation* yang dicadangkan dapat mengutamakan pesakit dengan berkesan kerana pesakit yang berada di tahap kecemasan yang tinggi diutamakan terlebih dahulu. (2) Bagi pengesahan objektif, perbandingan menunjukkan bahawa skor kumpulan pertama adalah yang tertinggi dengan nilai min *0.013*, menunjukkan bahawa keputusan *prioritisation* adalah sama. (3) Dalam penilaian, berkenaan senario, algoritma yang dicadangkan mempunyai kelebihan ke atas kerja penanda aras yang meliputi sama ada *triage* atau *prioritisation* dengan nilai peratusan 34.3% dan 50%. Implikasi kajian ini dapat mengenal pasti tahap *triage* dan kedudukan skala besar pesakit yang menghidapi penyakit jantung kronik yang boleh digunakan untuk menyediakan perkhidmatan dan rawatan berdasarkan status kecemasan. Kesimpulannya, penemuan utama menunjukkan bahawa kajian ini akan meningkatkan prestasi *triage* dan *prioritisation* dalam persekitaran teleperubatan.

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LIST OF ABBREVIATIONS

ASNET	Ad Hoc Sensor Networks
AF	Atrial Fibrillation
AIFS	Arbitration Interframe Space
AODV	Ad hoc On-Demand Distance Vector
BP	Blood Pressure
CAP	Contention Access Period
CBA	Cost–Benefit Analysis
CFP	Contention Free Period
DCC-MAC	Dynamic channel Coding MAC
DM	Decision Making
ECG	Electrocardiogram
ED	Emergency Departments
EDCA	Enhanced Distributed Channel Access
E-health	Electronic Health
EHR	Electronic Health Record
EM	Emergency Medicine
EMI	Electromagnetic Interference
EMS	Emergency Medical Services
FIFO	First In First Out
GP	General Practitioner
GPOS	General Purpose Operating Systems

GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HEMS	Helicopter Emergency Medical Services
HIPAA	Health Insurance Portability and Accountability Act
HM	Home Monitoring
HR	Heart Rate
HRV	Heart Rate Variability
ICU	Intensive Care Unit
IoT	Internet of Thing
ISET	Instrument for SElf-Triage
LOS	Length of Stay
MAC	Media Access Control
MCDM	Multi Criteria Decision Making
MCI	Mass Casualty Incident
MH	Mobile Hospital
MLAHP	Multi-layer Analytic Hierarchy Process
MSHA	Multi-Source Healthcare Architecture
OS	Operating Systems
Pc	Personal Computer
PC	Priority Code
PDA	Personal Digital Assistants
PEA	Priority based Energy Aware
PHDs	Personal Healthcare Devices
PHEIS	Prehospital Health Emergency Information System

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PMAC	Priority MAC
QoE	Quality of Experience
QoS	Quality of Service
RF	Radio Frequency
RPM	Remote Patient Monitoring
RTOS	Real-Time Operating System
R.T.S	Revised Trauma Score
RTS/CTS	Request To Send-Clear To Send
SD	Standard Deviation
SMS	Short Message Service
SNODEs	Sensor Nodes
SOA	Service Oriented Architecture
SpO2	Blood Oxygen Saturation Level
STEMI	ST Elevation Myocardial Infarction
TCNG	Traffic Control Next Generation
TDMA	Time-Division Multiple-Access
TMC	Tele-medicine Center
TOPSIS	Technique for Order Performance by Similarity to Ideal Solution
TPE	Time to Physician Evaluation
TPT	Telemedical Physician Triage
TXOP	Transmission Opportunity
UCC	Urgent Care Center
UHF	Ultra High Frequency
UR	URgent traffic
UWB	Ultra Wide Band

WBAN	Wireless Body Area Network
WBASN	Wireless Body Area Sensor Network
WiLD	WiFi-based Long Distance
WMSN	Wireless Multimedia Sensor Network
WPD	Wavelet Packet Decomposition

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents the research topic, problem statement and research objectives. A brief background of the research is presented in Section 1.2. Section 1.3 identifies and introduces the statement of the problem on which the research direction is based. Sections 1.4 and 1.5 describe the research questions and objectives. Section 1.6 presents the link between research questions and objectives. Section 1.7 discusses the significance of the study. Section 1.8 discusses the scope of the research and Section 1.9 described the operational definition. The main thesis structure is briefly described in Section 1.10. Finally, this chapter is summarised in Section 1.11.

1.2 Research Background

Telemedicine is currently a global trend towards bringing health services as close to the patient as possible. This technology can be applied to several situations, such as aiding doctors and patients in an emergency case or at home. The primary purpose of all telemedicine applications is to improve the well-being of patients and provide rapid and cheap medical expertise to people in need, usually those in remote areas that are underserved. Real-time remote patient monitoring is an important issue in telemedicine (Kalid, Zaidan, Zaidan, Salman, Hashim, & Muzammil, 2018), which can lead to development of evolving network technologies and wireless communications at any time and place with the concept of 'connected healthcare' (Qiao & Koutsakis, 2008). Remote patients refer to those who live far from hospitals and use telemedicine (Baig & Gholamhosseini, 2013; Okura et al., 2016).

In electronic health systems worldwide, chronic diseases are increasingly becoming a major concern. In the United States, the clinical expenditure on chronic diseases is projected to reach 80% of the total medical costs by 2020 and more than 150 million people will suffer from chronic diseases. Chronic heart disease is a severe disease involving various types and clinical manifestations. Cardiac arrhythmia is life-threatening and can cause heart problems, arrest and sudden death. Approximately 55% of patients with heart diseases die from arrhythmia according to a medical report in 2010 by the American Heart Association (O. H. Salman, Zaidan, Zaidan, Naserkalid, & Hashim, 2017).

Triage is an emergency medical method that categorises the severity of the case of patients and determines the order of aid (Tomozawa, Oguchi, Shigeno, & Okada, 2009). Automation of this task could significantly improve the quality of care and hospitalisation of patients to save as many lives as possible. During disasters, hospitals can be overwhelmed and paediatric specialists who care for injured children are insufficient (Burke et al., 2012). Emergency departments (ED) are often overcrowded, and trained staff uses triage systems to ensure timely treatment of patients with the most urgent need (Eijk, Bettink-Remeijer, Timman, & Busschbach, 2015). This technology also enables physicians to conduct triage and help prioritise rescue operations by tending to the most critical patients (Murphy et al., 2013). The rapid delivery of patient measurements is extremely important in terms of providing reliable data in emergency care and reliable (Zvikhachevskaya, Markarian, & Mihailova, 2009).

Patient prioritisation is carried out to provide each of them with healthcare services in due course. Based on the severity of the condition and vital signs of patients, rescuers determine treatment and transportation priorities during the first phase of the operation. The first phase usually starts with immediate life-saving treatments for the most affected victims, followed by identification, labelling and follow-up of patients (Rodriguez et al., 2014). Patients in critical conditions in local and ED queues are given priority (Xiong et al., 2012).

For the current scenario of triage and prioritisation studies, scholars have developed a new model to prioritise ‘Large-scale data’ in 500 patients with chronic heart disease based on multi-criterion decision-making during disasters and peak seasons (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018). This study conducted prioritisation based on different symptoms and evaluated their emergency levels through four main measurements: electrocardiogram (ECG), oxygen saturation sensor, monitoring of blood pressure and non-sensory measuring tool, namely, text frame. A multi-source framework has been proposed to support advanced healthcare applications (O. Salman, Rasid, Saripan, & Subramaniam, 2014). This study proposes Multi-Source Healthcare Architecture (MSHA), which considers multiple sources: sensors (ECG, SpO_2 and blood pressure) and text inputs from network devices for wireless and wireless body area network (WBAN) devices. The proposed algorithm is used to enhance healthcare scalability performance by improving remote triage and patient prioritisation.

These studies present triage at the first stage and use the outcome in prioritisation; they then present overall prioritised patients in one platform, which is considered a lack point. In this regard, a new solution that can triage patients into different levels should be developed to prioritise patients within each level based on their emergency status.

1.3 Research Problem

In an emergency situation, the highest priority should be given to patients with the most emergent case, whereas the lowest priority should be given to patients with the least emergent case compared with other patients in the telemedicine environment

(Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018). Different health conditions cause difficulty in deciding who should be treated first among remote patients with chronic heart disease (P. Sarkar & Sinha, 2014).

Triage determines the severity of patients' condition in ER to save their lives (Moreno et al., 2016). The weakness of previous works studying triage is that the prioritisation of patients within each triage category is not considered (O. Salman et al., 2014). In a proposed model, the order of casualties for treatment and transport was not determined (O. Salman et al., 2014).

Prioritisation is important to deliver patient records quickly and reliably, especially in emergency situations (Algaet, Noh, Shibghatullah, Milad, & Mustapha, 2014). However, in reality, first-come, first-serve (FCFS) care is provided to patients in an ED (Claudio & Okudan, 2009). FCFS cannot be used in actual situations, so a rapid, well-informed and timely decision is needed to prioritise patients (Claudio & Okudan, 2009; Tan, 2013).

Improper triage and patient prioritisation can lead to incorrect strategic decisions that can endanger the lives of patients (Kalid, Zaidan, Zaidan, Salman, Hashim, & Muzammil, 2018). In a medical situation, if triage is performed individually, then prioritisation of patients within each category of triage cannot be determined. Such case will cause a lack in prioritisation performance. If patients only receive treatment with triage but without prioritisation, then most urgent patients will be at risk.

In this research, several issues can be affected on the performance of the triage and prioritization patients with chronic heart disease. Support vital signs is considered the first issue, which used in the triage and prioritisation, and it is important in evaluating a patient's condition by using several medical sensors (Sakanushi et al., 2013; O. Salman et al., 2014). Support chief complaints is considered the second issue, which used in the patient triage and prioritisation because the remote monitoring of healthcare requires non-sensory data (O. Salman et al., 2014). Targeted tier is the third issue, which used to identify the level of triage and prioritisation.

Choosing suitable tier to be responsible for triage and prioritization processes is critical issue because of there are three levels of architecture are available for remote monitoring of health and telemedicine: Tier 1 (sensors), Tier 2 (base station) and Tier 3 (remote server) in the remote monitoring of health and telemedicine (Claudio, Kremer, Bravo-Llerena, & Freivalds, 2014; O. Salman et al., 2014). Scalability is the fourth issue, which shows whether scalability has been accommodated and handled in triage and prioritization processes or not. Scalability is a considerable concern in remote health-care monitoring that leads to accommodate and handle several patients in due course (O. Salman et al., 2014).

Remote environment is considered the fifth issue, which shows whether patient triage and prioritisation are performed in a remote environment or not. The overwhelming heterogeneity of patient data in remote environments causes problems in triage and prioritization (P. Sarkar & Sinha, 2014). Moreover, handling large amount of data for triage and prioritisation processes is considered the sixth issue, which involves the handling of large numbers of patients with overwhelming data from multiple sources (P. Sarkar & Sinha, 2014). Prioritisation in terms of category/order is the seventh issue, which shows whether categories or order methods support prioritization or not. Most methods classify patients as priorities, and patient order is usually determined according to the first-come-first-serve principle (Claudio et al., 2014).

Features weighting is the eighth issue, which shows the weighting technique used. A medical server side that scores a patient could provide more weight to the vital features than to other features of less interest on the basis of the experts' judgements and preferences (Abbasgholizadeh Rahimi, Jamshidi, Ait-Kadi, & Ruiz, 2015; Claudio & Okudan, 2009). Multi-criteria ranking is the ninth issue, which shows whether a study dealt with multiple criteria during prioritisation. The prioritisation of patients is a complex problem in decision making (Ashour & Okudan, 2010; Claudio & Okudan, 2009; Göransson, Ehnfors, Fonteyn, & Ehrenberg, 2008; Seising & Tabacchi, 2013) and the decision is made based on a set of attributes (Faulin, Juan, Grasman, & Fry, 2012). Patient prioritisation accuracy is the tenth and last issue, which shows the accuracy of patient prioritisation. In the exact ranking of patients, prioritisation accuracy is reflected in the urgency of the situation, taking into consideration the patients' medical condition. Accuracy also reflects the recognition of the slight differences between patients during an urgent situation (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018).

Numerous prioritisation models have been developed (Kalid, Zaidan, Zaidan, Salman, Hashim, Albahri, et al., 2018; Kalid, Zaidan, Zaidan, Salman, Hashim, & Muzammil, 2018; O. Salman et al., 2014). In these models, medical staff prioritises patients without performing accurate triage because these models follow and depend on the patients' raw data. For example, if existing prioritisation methods rank patients depending on their raw data, then sick patients may be prioritised over high-risk patients. Many categories and standards are present, such as two, three and four during triage (O. Salman et al., 2014). The decision maker must categorise patients at different levels based on their conditions and prioritise each category individually to increase prioritisation performance. This process is called prioritisation of emergency for emergency and urgent for urgent. The present research deals with the processes of triage and prioritisation for remote patients for telemedicine. The problem statement is illustrated in Figure 1.1.

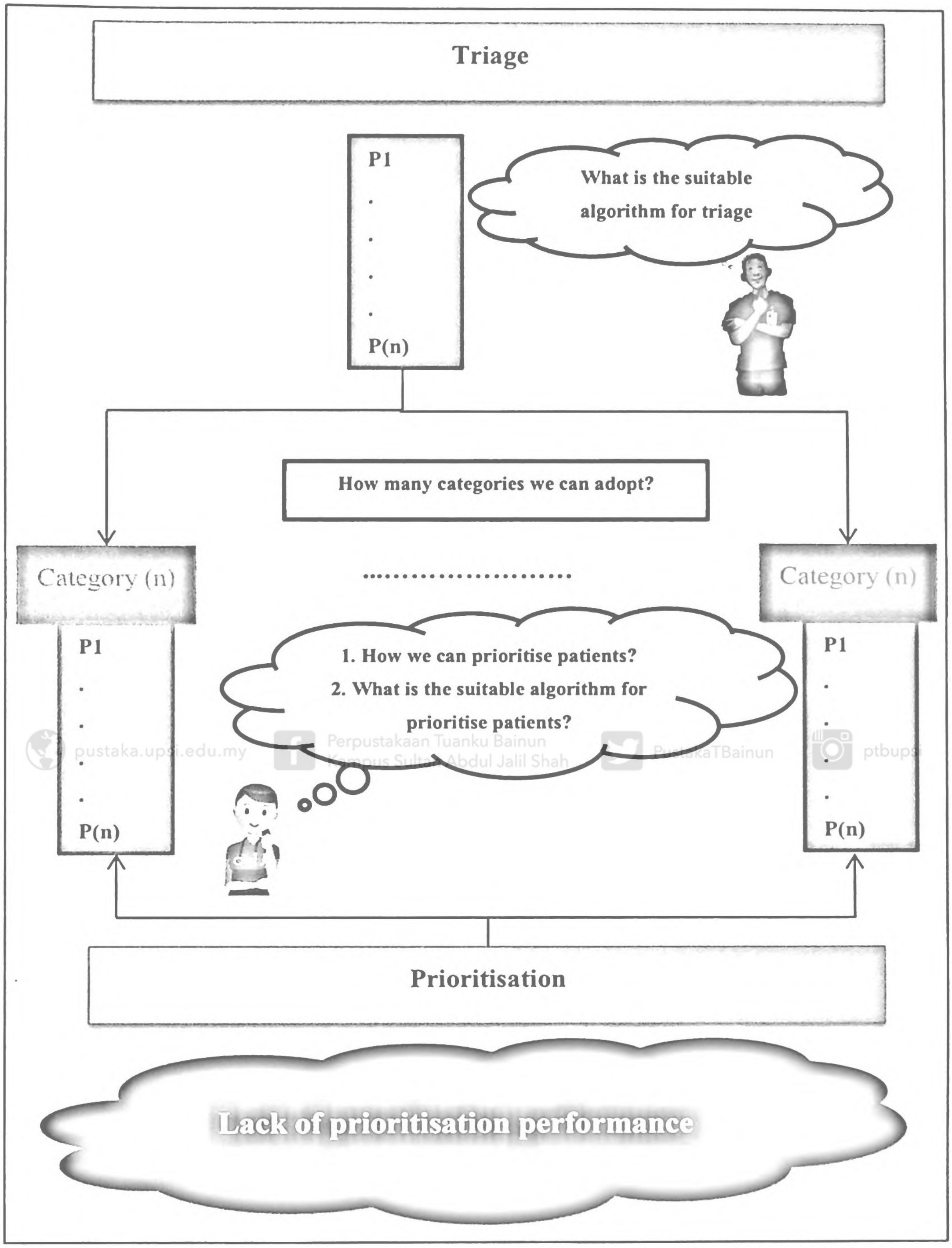

Figure 1.1. Problem statement configurations

1.4 Research Questions

The following research questions are formulated to guide this research:

1. What are the available triage and prioritisation applications?
2. What are the requirements needed to propose a triage and prioritisation algorithm for telemedicine environment?
3. What are the suitable methods for developing a triage and prioritization algorithm for patients with chronic heart disease?
4. Is the proposed triage and prioritisation algorithm systematically valid?
5. Is the performance of the proposed triage and prioritisation algorithm better than existing studies?

1.5 Research Objectives

The research goals are as follows:

1. To investigate and highlight the weaknesses of previous studies that are related to telemedicine applications and focus on triage and prioritization.
2. To develop a new algorithm for triage and prioritization patients with chronic heart disease based on evidence theory and integration of MLAHP-TOPSIS methods.
3. To validate the proposed algorithm objectively.
4. To evaluate and determine the findings between the proposed and benchmark study.

1.6 Connections among Research Objectives and Research Questions

In this section, all research questions are answered by the research objectives. Each objective is linked to one or two questions. The connection between research objectives and research questions is presented in Table 1.1.

Table 1.1

Connection amongst Research Objectives and Research Questions

Research objectives	Research questions
1. To investigate and highlight the weaknesses of previous studies that are related to telemedicine applications and focus on triage and prioritization.	1. What are the available triage and prioritisation applications? 2. What are the requirements needed to propose a triage and prioritisation algorithm for telemedicine?
2. To develop a new algorithm for triage and prioritization patients with chronic heart disease based on evidence theory and integration of MLAHP-TOPSIS methods.	3. What are the suitable methods for developing a triage and prioritization algorithm for patients with chronic heart disease?
3. To validate the proposed algorithm objectively.	4. Is the proposed triage and prioritisation algorithm systematically valid?
4. To evaluate and determine the finding between the proposed and benchmark study.	5. Is the performance of the proposed triage and prioritisation models better than other existing studies?

In Table 1.1, the first objective is answered by the first and second questions. The second, third and fourth objectives are answered by the third, fourth and fifth questions, respectively.

1.7 Significance of the Study

The benefits of using triage and prioritisation in telemedicine are interesting. Some of the reported advantages are grouped into categories and compared for further discussion. The advantages are illustrated in Figure 1.2.

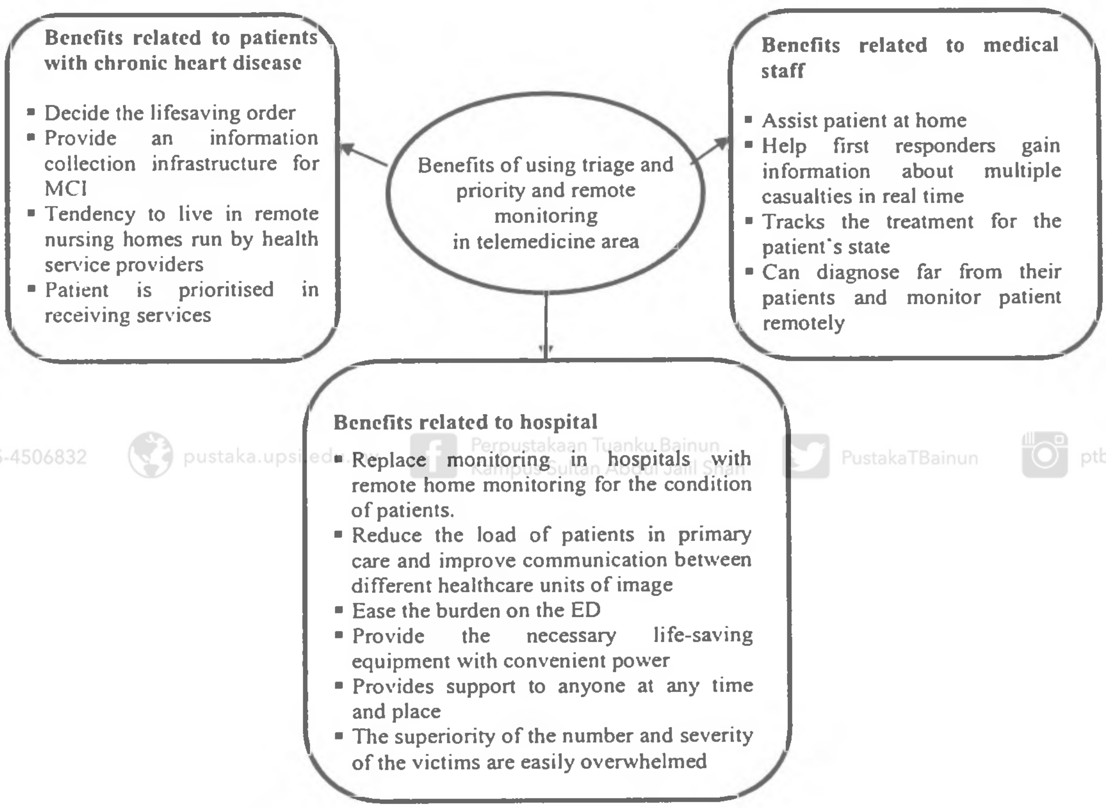

Figure 1.2. Categories of the Advantages of Using Intelligent Measurement for Triage, Prioritisation and Remote Monitoring in Telemedicine

1.7.1 Benefits to Patients with Chronic Heart Disease

Major accidents, such as rail accidents, and major disasters, such as hurricanes and typhoons, have caused injuries to many patients. In these cases, triage, an emergency life-saving method, is introduced to determine the life-saving order (i.e. emergency level) based on the patient's blood pulse, spontaneous respiration and oxygen and to save many lives (Kobayashi, Tomozawa, Tamura, Shigeno, & Okada, 2010). The triage also provides an easy-to-use, scalable and durable information collection infrastructure for MCI. The triage will help to rapidly evaluate patients affected by disasters, identify response capabilities required and manage assets when they arrive on the scene (Ganz et al., 2014).

Millions of people die each year from various coronary heart diseases. Elderly people are more susceptible to these diseases, and most of them live in remote hospitals for health care. Remote aging care facilities should be equipped with systems that can wirelessly and continuously monitor the ECG of elderly (Khalil & Sufi, 2008). Each patient receives priority services, and each service requires a priori known time slot to serve patients at their home (Danach, Hassan, Khalil, & Gelareh, 2015).

A patient with a wireless vital sensor can simply walk in a room where multiple receivers are freely installed. The receivers are directly connected to a personal computer (PC) at the nursing station where ECG, 3D acceleration, heart rate (HR) and behaviour on the PC display can be continuously monitored. Several events, such as arrhythmia, and thresholds of HR and body temperature can be pre-set as urgent. The system easily detects high body temperatures and increased HR (Hara et al., 2012). The WBAN provides patients with continuous health monitoring without restrictions on their normal daily activities (Negra, Jemili, & Belghith, 2016).

1.7.2 Benefits to Medical Staff

In disasters, such as collapse of a building, respondents can safely remove a trapped victim when they are finally found for 4 to 10 h. To enhance survival, respondents and medical staff must comfort the victims, monitor their condition during this period and keep them calm (Murphy et al., 2013). The system can help first responders gain information on multiple casualties in real time, enabling rapid and optimal allocation of resources and tracking patient's condition for appropriate emergency treatment (Moreno et al., 2016). In this regard, medical experts can rapidly perform triage and prioritise rescue efforts by tending the most critical victims (Murphy et al., 2013).

Telemedicine can improve the efficiency of and the access to healthcare providers in countries with a low doctor per patient ratio. For example, in Rwanda is one of those countries with a very low ratio of doctors per patient, that is, six doctors per 100,000 patients in 2010. Neighbouring countries, namely, Uganda and Kenya, have eight and 14 doctors per 100,000 patients (Brown & Rudahinduka, 2014).

Advanced wired and wireless technologies can increase network/capacity and performance and also affect the medical environment. Doctors can distantly diagnose their patients and ask other doctors for medical advice. In particular, when a typhoon, flood or massive medical emergency explosion occurs, medical data required for patient care are more crucial than usual. Medical data including vital signals and video data on telemedicine and X-ray must be transmitted reliably because they are tied directly to the life of the patient (Lee, Lee, & Chung, 2008). The telemedicine system can use and exchange various and durable patient data to allow remote tracking of patients by the physician. Patients can be efficiently diagnosed by adjusting the frame rate in real time with variable transmission speed over wireless networks (Hong et al., 2009).

Wireless Body Area Sensor Networks (WBASNs) can increase the quality of patient monitoring and health services in real time. With the use of WBASN, medical experts can remotely access and analyse patient data. These networks use biosensors to collect biomedical data from patients by using special intelligent nodes. The nodes can be worn or implanted in the human body (Puri, Challa, & Sehgal, 2015). This method is tedious and unscalable, particularly if the number of victims in a given mission exceeds the number of respondents. Pararescue jumpers, combat rescue officers and similar medical rescue agencies are searching for sensors for medical signs and telemetry solutions to mass casualty problems, where a small medical rescue team can rescue and sustain the lives of many victims in critical conditions (Renner et al., 2014).

Disasters are low-frequency, high-stake events. Telemedicine can be a useful complement for disaster triage paramedics, who monitor patient records, such as changes in blood pressure and severity of the condition, and communicate in real time with the sink node. The paramedics assume that these tag types are used. The two types of data used in triage scenes are 'normal message', which indicates the status of low-severity patients, and 'emergency message', which implies the status of patients injured.

1.7.3 Benefits to Hospital

Medical institutions face serious problems, such as growing elderly populations and lack of doctors. The realisation of slightly shortened hospital stays and home healthcare support is intended to tackle these problems. Several healthcare systems attempt to replace hospital visits with remote home monitoring (HM) of patient conditions because of considerable advances in wireless information communication technology (ICT) and signal processing technology (Sugano et al., 2011). HM also reduces the burden on patients with primary care and improve communication among different health units to reduce the burden on ED (Radhakrishnan, Duvvuru, & Kamarthi, 2014). Community hospitals can improve the triage of paediatric patients and reduce the need for patient transfer (LaBarbera et al., 2013).

Using wireless networks is important and relevant to provide information on out-of-hospital incidents because healthcare networks are expected to operate at any time, allocate available resources and ensure quality of service (QoS) for specific applications in healthcare. The use of applications, such as medical databases, electronic health records (EHRs) and text/audio/photo/video medical data, in underserved areas, such as rural health centres, ambulances, ships, aircraft and home environments, may be supported by medical services (Zvikhachevskaya et al., 2009).

The majority of systems used in hospitals are wired technologies, which require power of the infrastructure of the building and used for blood pressure monitoring and ultrasonic of pulse oximetres and X-ray. These technologies offer necessary life-saving equipment a convenient way to obtain power. The power needs of these systems can be satisfied as long as no prolonged blackouts occur, such as those in disaster situations (Smalls, Wang, Li, Chen, & Tang, 2009). WBAN is a low-cost technology with a remote monitoring system for patients by using wireless media and can be regarded as a purpose-specific wireless sensor node network that provides continuous support at all times and places for health monitoring (Ambigavathi & Sridharan, 2015). Mobile healthcare is a new paradigm, in which evolving wireless and network technologies are combined with the concept of 'connected healthcare' (Qiao & Koutsakis, 2008).

MCI is an event in which the number of severely injured victims can easily overwhelm resources, such as staff and equipment, for emergency medical services (EMS). An MCI can involve a wide range of respondents and agencies, including paramedics, ambulances, fire fighters or police, indicating the high level of logistics required for their coordination. The main purpose of MCI is to help all victims efficiently and return as quickly as possible to standard care routines to save as many lives as possible (Rodriguez et al., 2014).

1.8 Research Scope

This research is a cross-domain involving healthcare and expert system algorithms and aims to solve the triage and prioritisation problem for remote patients. The study involves various methods because the problem is classified as a multidisciplinary problem. Five hundred patients with chronic heart disease as secondary data are used in the experiments as a case study for triage and prioritisation of patients.

The outcomes of the research indicate the research type. Results are expected to serve as an algorithm to enhance triage and prioritisation for a wide range of patients with chronic heart disease in telemedicine. The proposed algorithm is validated objectively and statistically. Furthermore, different scenarios and checklist benchmarking have been provided for method evaluation. The general scheme for our research and the view that represents the research method, type and domain are presented in Figure 1.3.

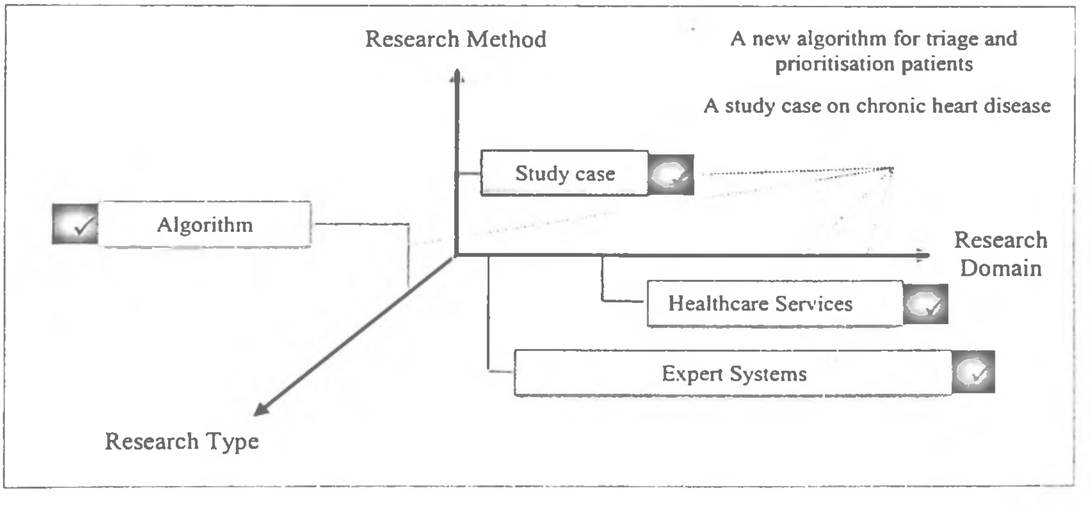

Figure 1.3. General Scheme and Scope of the Study

1.9 Operational Definition

In this section, an operational definition is presented. The following are definitions of terms used in this study including triage, prioritisation, evidence theory, MLAHP, TOPSIS and patients.

1.9.1 Triage

Triage in this study refers to chronic heart disease patients which are used as reference to measure vital signs using various medical devices. Priority code based on four features of an ECG sensor, BP sensor, SpO2 sensor and text are used as a solution to triage patients and to identify the emergency case for each patient which is risk, urgent, sick, cold state and normal.

1.9.2 Prioritisation

In this study, prioritisation refers which patient will be treats first for each triage levels. The most urgent patients will be given more urgent attention than others.

1.9.3 Evidence Theory

Evidence theory in this study refers to four features of an ECG sensor, BP sensor, SpO2 sensor and text to determine the emergency level of chronic heart disease patients. Patients were triaged using evidence theory to classify them according to emergency cases and separate them into five categories which is risk, urgent, sick, cold state and normal.

1.9.4 MLAHP

MLAHP in this study refers to allocates weights for each main feature (ECG sensor, BP sensor, SpO2 sensor and text) and each main feature is rated in the hierarchy for each patient. MLAHP is used to obtain balancing ratio scales. An arithmetic mean is used for the final weighting of the preferences of the six experts to correctly eliminate the variation.

1.9.5 TOPSIS

TOPSIS in this study can rank and order the patients according to their emergency status and show them in a queue in each triage level which is TOPSIS can assign the rank to each patient at each triage level.

1.9.6 Patient

In this study, chronic heart disease patients were used as reference to measure vital signs using various medical devices. 500 datasets of patients with chronic heart disease were used in this study.

1.10 Research Organisation

This research consists of six chapters. Chapter one provides the background and motivation for research and research problems, questions and objectives. The links among research objectives, questions and scope are also discussed. The remaining sections are arranged as follows:

Chapter Two: This section presents a systematic review of the protocol for telemedicine area followed by an overview of studies on triage and prioritisation. This chapter also examines the challenges of previous studies and discusses the remote health monitoring system with chronic heart disease and medical sensor for the case study. The standards and guidelines for the triage and prioritisation are also discussed. The disadvantages of studies on triage and prioritisation are listed. Such limitations should be overcome by developing a new algorithm.

Chapter Three: This section provides the full description of the research methodology, which consists of three phases, namely, preliminary study, development and validation and evaluation phases. Each phase corresponds to and addresses one or more research objectives.

Chapter Four: This chapter presents the results based on the proposed method in six sections, with each section having its own aims. The sections show the datasets of patients with chronic heart disease and the new algorithm result with two subsections, namely, triage and prioritisation results of patients. Evaluation and validation comprise several steps to test the performance of the algorithm on improving and enhancing patient triage and prioritisation for telemedicine environment to overcome the research problems.

Chapter Five: The conclusion is reported, and the goals and contribution of this research are presented. The areas to be pursued are also suggested for future work.

1.11 Chapter Summary

This chapter provides a background about triage and prioritisation for telemedicine. This research considers triage and prioritisation as a complex decision-making problem and evaluates prioritisation performance. The research question and objectives mainly focus on improving triage and prioritisation performance. The connection between research objectives and questions is explained. In the significance of the study, the motivation is stated. The research scope explains the methods conducted. The general idea of the other chapters is presented in the final part of this chapter.