



UNIVERSITI PUTRA MALAYSIA

***PRIVACY-PRESERVING FRACTAL HEALTHCARE INFORMATION
SYSTEM MODEL BASED ON K-ANONYMIZATION TO IMPROVE
COLLABORATION AMONG PHYSICIANS***

LUMA FAWAZ JARALLAH

FSKTM 2018 6



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By

LUMA FAWAZ JARALLAH

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
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Master of Science**

October 2017

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DEDICATION

This thesis is dedicated to my beloved *Parents*

(Prof. Fawaz Jarallah & Mrs. Hanaa Ismail)

For their endless love, encouragement and unconditional support in all my life

And

Especially to my awesome *Husband, (Dr. Azher)*

Anything good that has come to my life has been because of your example

And

My lovely *Children (Rand, Banan, Ibrahim)*

Love you always and forever

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in
fulfillment of the requirement for the Degree of Master of Science

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By

LUMA FAWAZ JARALLAH NAIF

October 2017

Chairman : Associate Professor Masrah Azrifah Azmi Murad, PhD
Faculty : Computer Science and Information Technology

Transformers are considered as a key in the transmission and distribution of electrical energy. The healthcare sector is a very important industry to serve high-quality services and healthcare treatment to citizens in every country in the world. In the field of healthcare, organizations include individual centres supported by the separate healthcare information systems (HISs), such as in hospitals. Health information systems (HISs) help to ensure that patients immediately receive appropriate treatment. In addition, the healthcare information system (HIS) can be employed as a tool to communicate between skills of members. The collaboration model has become an important requirement in the healthcare environments (Hospitals) to exchange information among physicians that can inform on critical decisions related to healthcare services. In the recent literature review, many studies mentioned that there is a lack of collaboration among hospitals in most developing countries. Such a lack of collaborative effort among physicians based on HIS can affect the medical research services due to the manual and stand-alone systems where these systems do not have real-time technology. Hence, there is a need for an integrated HIS to ensure a collaborative healthcare environment. The fractal approach has been successfully used in designing integrated collaborative HISs which provide an open, autonomic, flexible and collaborative method for linking system units. The term “collaboration” in the field of healthcare is defined as the communication that occurs among healthcare practitioners when sharing information and skills regarding patient care. Sharing this healthcare information among different organizations can significantly benefit both medical treatment and scientific research in relevant sectors. However, sharing this data would directly pose a threat to patients’ privacy. Data sharing in healthcare remains a challenge due to widespread privacy concerns. The privacy preservation of the sharing of information is a crucial impediment to achieve collaboration through health research using HISs. This study has focused on protecting the privacy of sharing information based on fractal

healthcare information systems using the K-anonymization model. This study aims:

- i) To determine the current level of collaboration among physicians; with the factors that affect this collaboration in selected Malaysian hospitals based on privacy preservation;
- ii) To develop and evaluate a Privacy Preserving Fractal Healthcare Information System (PPFHIS) model to enhance sharing of information in the distributed HIS based on privacy preservation.

The data collection has been carried out at two public hospitals in Selangor, as a sample study. The quantitative approach used is the questionnaire survey. The questionnaires were distributed among one hundred and fifty physicians; however, only one hundred and ten questionnaires were completed and considered for analysis. The result showed the lack of collaboration among physicians. This lack of collaboration occurred due to significant factors, such as the privacy issue during information sharing between different hospitals; the system units maintaining autonomy; large amounts of data being difficult to manage and control according to the mixed system (paper and computerized system) used in the hospitals; the new knowledge is not being acquired in a timely manner. Three experts validated the system model and the system prototype before users' evaluation. The PPFHIS was implemented by the fifty respondents from the two hospitals to evaluate the system usability and the effect of this system in improving collaboration among physicians. Results indicated that the PPFHIS is satisfactory (system usability scores = 76.05). In addition, the privacy concerns significantly affect the sharing of information among physicians. Nonetheless, privacy preservation for the sharing of information improves the collaboration in medical research. These results demonstrate that the combination of Fractal features in sharing information and the K-anonymization model to protect the privacy through HIS improve the collaboration among physicians and enhance healthcare services as well as research activities.

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

**MODEL PENJAGAAN KESIHATAN PEMELIHARAAN PRIVASI
FRAKTAL DALAM SISTEM MAKLUMAT BERDASARKAN K-
ANONIMISASI UNTUK MEMPERBAIKI KOLABORASI DI KALANGAN
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Pengubah Sektor penjagaan kesihatan merupakan industri yang sangat penting untuk menyediakan perkhidmatan yang berkualiti tinggi dan rawatan jagaan kesihatan kepada rakyat di setiap negara di dunia. Dalam bidang penjagaan kesihatan, organisasi termasuk pusat-pusat individu disokong oleh sistem maklumat penjagaan kesihatan (HIS) yang berasingan, seperti di hospital. Sistem maklumat penjagaan kesihatan (HIS) membantu memastikan pesakit menerima rawatan serta-merta yang sesuai. Di samping itu, sistem maklumat penjagaan kesihatan (HIS) boleh digunakan sebagai alat untuk berkomunikasi di antara kemahiran anggota-anggota. Sistem kolaborasi telah menjadi satu keperluan yang penting di dalam persekitaran penjagaan kesihatan (Hospital) untuk bertukar-tukar maklumat di kalangan pakar perubatan untuk memaklumkan mengenai keputusan penting yang berkaitan dengan perkhidmatan penjagaan kesihatan. Dalam kajian kepustakaan baru-baru ini, banyak kajian menyebut bahawa terdapat kekurangan kolaborasi antara hospital di kebanyakan negara membangun. Kekurangan usaha kolaborasi di kalangan pakar perubatan berdasarkan HIS seperti ini boleh menjejaskan perkhidmatan penyelidikan perubatan oleh kerana sistem manual dan berdikari di mana sistem-sistem ini tidak mempunyai teknologi masa nyata. Justeru itu, ada keperluan untuk kolaborasi HIS yang disepadukan untuk memastikan persekitaran jagaan kesihatan yang bekolaborasi. Pendekatan fraktal telah digunakan dengan jayanya untuk mereka bentuk HIS bekolaborasi bersepadu yang menyediakan kaedah terbuka, autonomik, fleksibel dan bekerjasama untuk memautkan unit-unit sistem. Istilah “bekerjasama” di bidang penjagaan kesihatan didefinisikan sebagai komunikasi yang berlaku di kalangan pengamal penjagaan kesihatan apabila berkongsi maklumat dan kemahiran mengenai jagaan pesakit. Perkongsian maklumat penjagaan kesihatan ini di kalangan organisasi yang berlainan boleh dengan ketaranya memanfaatkan kedua-duanya rawatan perubatan dan penyelidikan saintifik di sektor-sektor yang terlibat. Walau

bagaimanapun, berkongsi data ini akan secara langsung merupakan ancaman kepada privasi pesakit. Perkongsian data di bidang penjagaan kesihatan masih merupakan cabaran kerana kebimbangan yang meluas mengenai privasi. Pengekalan privasi bagi perkongsian maklumat ialah halangan terpenting terhadap pencapaian kerjasama melalui penyelidikan kesihatan menggunakan HIS. Kajian ini bertujuan untuk: 1) menentukan paras kolaborasi semasa di kalangan pakar perubatan, dengan faktor-faktor yang mempengaruhi kolaborasi di hospital-hospital Malaysia yang terpilih berasaskan pemeliharaan privasi; ii) Untuk membangunkan dan menilai suatu model Sistem Maklumat Pemeliharaan Penjagaan Kesihatan Fraktal (PPFHIS) untuk mempertingkatkan perkongsian maklumat di HIS yang diagihkan berasaskan pemeliharaan privasi.

Pengumpulan data telah dijalankan di dua hospital awam di Selangor, sebagai kajian sampel. Pendekatan kuantitatif yang digunakan ialah tinjauan soal selidik. Soal selidik diedarkan di kalangan seratus lima puluh pakar perubatan; walau bagaimanapun, hanya seratus sepuluh soal selidik telah diselesaikan dan dipertimbangkan untuk dianalisis. Hasilnya menunjukkan kurangnya kolaborasi di kalangan pakar perubatan. Kurangnya kolaborasi ini berlaku disebabkan oleh faktor-faktor penting, seperti isu privasi semasa perkongsian maklumat di antara hospital yang berbeza, unit-unit sistem berkenaan mengekalkan autonomi; jumlah data yang besar yang sukar untuk diurus dan dikawal mengikut sistem campuran (kertas dan sistem berkomputer) yang digunakan di hospital, serta pengetahuan baru tidak diambil alih dengan cara yang tepat pada masanya. Tiga orang pakar telah mengesahkan model sistem dan prototaip sistem itu sebelum penilaian pengguna. PPFHIS tersebut dilaksanakan oleh lima puluh responden dari dua hospital tersebut untuk menilai kebolegunaan sistem itu dan kesan sistem tersebut dalam meningkatkan kolaborasi di kalangan pakar perubatan. Keputusan menunjukkan bahawa PPFHIS adalah memuaskan (skor kebolegunaan sistem = 76.05). Di samping itu, kebimbangan privasi dengan ketaranya memberi kesan kepada perkongsian maklumat di kalangan pakar perubatan. Namun begitu, pemeliharaan privasi untuk perkongsian maklumat meningkatkan kolaborasi di dalam penyelidikan perubatan. Keputusan ini menunjukkan bahawa gabungan ciri Fraktal dalam berkongsi maklumat dan model K-anonimisasi untuk melindungi privasi melalui HIS memperbaiki kolaborasi di kalangan pakar perubatan dan meningkatkan perkhidmatan penjagaan kesihatan serta aktiviti penyelidikan.

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

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LIST OF ABBREVIATIONS

CRC	Clinical Research Center
EHRs	Electronic Health Records
EPR	Electronic Patient Record
ERD	Entity Relationship Diagram
FHIS	Fractal Healthcare Information System
HIPPA	Health Insurance Portability and Accountability Act
HISs	Healthcare Information Systems
HL7	Health Level 7
ICT	Information and Communication Technology
ISs	Information Systems
NGO	Non-Government Organization
NIH	National Institute of Health
PACS	Picture Archiving and Communication System
PPDP	Privacy Preserving Data Publishing
PPFHIS	Privacy Preserving Fractal Healthcare Information System
R&D	Research and Development Unit
RQs	Research Questions
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Research Background

One of the most important industries in the world saddled with the responsibility of providing high quality services and treatment to people is the healthcare sector. One of the organizations that are found in the field of healthcare is individual centres such as hospitals which are supported by separate healthcare information systems (HISs) (Fedele, 1995). HISs were first introduced to hospitals 30 years ago, in order to enhance the work of medical staff, (T.-H. Yang et al., 2011). In hospitals, HISs are used for the collection and storage of electronic information like doctors' schedules, patients record and more (Al-Khawlani, 2009). Healthcare information systems (HISs) ensures that timely and proper treatment is received by patients. These HISs have been tailored to fit various services and departments of organizations that provide healthcare services like radiology information systems (RIS), Picture archiving and communications systems (PACS), laboratory information systems (LIS) and so on (K. Li & Yao, 2006).

HISs can be a crucial factor that can enhance collaboration among healthcare workers in terms of sharing of healthcare information because it plays a significant role in providing information about patients to administrative staff, nurses (Dong & Keshavjee, 2016). Boas et al., (2014) stated that the use of healthcare information system can be employed as a tool of communication skills to members of a group in order to improve the level of medical learning within the HISs. Basically, collaborative activities which enhance the delivery of healthcare services is supposed to be the main medical function of the components of HIS systems (VanVactor, 2012). Collaboration is regarded by many researchers as an adhesive which binds relationships, supports teamwork, and communication among all the stakeholders of a health organization (Dunham-taylor & Pinczuk, 2014). Findings of a study conducted by (Laschinger & Smith, 2013) revealed that 70% of the adverse events that occur are caused by lack of collaboration and communication among healthcare team members. The exchange of information that occurs among healthcare teams is regarded by many researchers as collaboration. However, in several developing countries HISs are mostly manual systems that are independent of each other. The manner in which healthcare systems in Malaysia, utilizes manual and independent systems has been described by (Hameed et al., 2011). He explained that majority of the systems do not possess mobile and real-time technologies. This is one of the causes of the failure in collaboration among healthcare providers. Therefore, in order to ensure that a collaborative healthcare environment is achieved, there is an urgent need for the development of integrated HISs (Ahmed & Yasin, 2014).

The main focus of this research is the collaboration between physicians as researchers in relation to using the HIS for sharing hospital information for the

purpose of research with protecting the privacy, inside the same hospital or among outside the hospitals in selected Malaysian hospitals in Selangor, Malaysia. The aim of this is for improving the collaboration among physicians so as to improve the research findings and services. Through the development of a flexible integrated collaboration HISs which supports information sharing, this aim will be achieved.

1.2 Problem Statement

In healthcare organizations like hospitals, healthcare information systems (HISs) plays a significant role in the provision and dissemination of healthcare information among medical staff particularly physicians as researchers (Rashid, 2014). Furthermore, collaboration is considered one of the crucial requirements for HISs (Ahmed & Yasin, 2014). In the healthcare field, the term “collaboration” is referred to as the communication that takes place among healthcare specialists during the exchange of skills and information related to the care of patients (Eikey et al., 2015). Both scientific research and medical treatment can benefit significantly from the sharing of healthcare information among different organizations (Rashid et al., 2012).

One of the major roles of modern healthcare systems is the sharing of healthcare information because the sharing of healthcare information enhances the delivery of quality care alongside the delivery of a wider range of services like the improvement of collaboration within the healthcare environment (Dong & Keshavjee, 2016; Wimmer et al., 2016)

Moreover, Findings of previous studies have revealed that the collaboration which exists among physicians when they share information using HISs for the treatment of patients in hospital environments of several developing nations, is very weak (Hameed et al., 2011; Ahlan & Ahmad, 2014). It has been found that this weakness is a result of autonomous and decentralized units as well as the absence of common goals in the healthcare systems with many HISs being independent of each other due to the divided nature of healthcare systems (Ahmed & Yasin, 2014). Collaboration among physicians and sharing of information is hindered by manual and disintegrated HISs systems found within healthcare systems thereby causing the under-utilization of healthcare resources because it is difficult to manage large data manually (Rashid, 2014). An integrated healthcare information system was developed using the fractal features which aimed at improving patient treatment, collaboration among physicians (Ahmed & Yasin, 2014). In order to implement integrated HISs effectively, there must be trust between the patient they serve and the providers who hold them, and the medical records can be retrieved and tracked in real time (Yee-Loong Chong et al., 2014; Ahmed & Yasin, 2014). One of the major problems faced by e-health platforms include the development of flexible, secure, efficient and reliable platforms because of how sensitive health data is; therefore, there is a need to take note of privacy concerns (Yahya Benkaouz & Erradi, 2015). However, the privacy of the patients will be threatened by the sharing of this data (Yahya Benkaouz & Erradi, 2015).

Due to privacy concerns, the sharing of healthcare data remains a huge challenge. Even though a number of researches have been conducted on the preservation of privacy, healthcare organizations have continued to show unwillingness to share medical data in accordance with the Health Insurance Portability and Accountability Act (HIPAA). The preservation privacy has continued to pose a challenge to the sharing of data as well as the integration of healthcare information systems (Wimmer et al., 2016).

Therefore, there is a need in the development of practical models which can strike a balance in the sharing of healthcare data and preservation of privacy while improving the collaboration among physicians (Ben-Assuli, 2015; Bertino, 2016; Y. Xu et al., 2014). Despite these privacy concerns, there is still a need for physicians as researchers to collaborate and communicate with each other so that the findings of the research which can enhance the delivery of healthcare services can be improved. Information is one of the major keystones in the field of healthcare. It is also crucial to tackle the issue of collaboration and information sharing among physicians in different institutions in accordance with the preservation of privacy.

1.3 Research Questions

In line with the problem statement, the research questions are explicated:

1. What are the factors that affect the existing levels of collaboration among physicians in the selected hospitals with regard to sharing information based on preserving the privacy?
2. How can an integrated Healthcare Information System model based on preserving the privacy, be proposed and evaluated to enhance the medical research collaboration among the physicians in the selected hospitals?

1.4 Research Objectives

The objectives that underline the way for the research are:

1. To analyse and propose the factors that affect the current levels of collaboration which exist among physicians in sharing information a based on privacy preserving in the selected hospitals.
2. To propose and evaluate an integrated Healthcare Information System model based on the privacy preserving to enhance the collaboration in terms of exchange medical research information among physicians.

1.5 Research Scope

The aim of this research is to determine the present levels of collaboration in sharing healthcare information among physicians as researchers in the healthcare environment. The significant factors which affect such collaboration are examined. More so, an integrated collaborative HIS model is proposed for the improvement of collaboration between the physicians in relation to the healthcare information sharing within the hospital and outside other. Considering the different types of physician's collaboration, particularly who conducting the medical research based on privacy preserving

1.6 Research Contributions

The major contribution of this study is the integrated healthcare information system which takes into consideration the preservation of privacy in order to improve the collaboration among physicians in hospitals by using HISs to share information. Thus, a Privacy Preserving Fractal Healthcare Information System (PPFHIS) model aimed at improving collaboration between physicians in relation to the exchange medical research information taking into consideration the issue of privacy preservation proposed in this study. The proposed model makes the physicians as medical researchers be able to access updated data required for their scientific research and healthcare activities directly from the integrated system.

It is expected that the system will minimize the challenges often faced by medical researchers in terms of obtaining data for medical research as well as other methods of treatment because the current method of obtaining such data involves a long process which is time consuming; the overall performance of health system can be affected by this impediment.

Asides that, this research is the first of its kind to investigate the preservation of privacy within fractal healthcare information model. Therefore, the current existing literature will be benefit from this study through the addition of new knowledge in this field. It will also serve as a base for future researchers that seek to conduct research on the usage of information technology, particularly integrated Fractal Healthcare Information Systems (FHISs) based on K-anonymization model.

1.7 Organization of the Thesis

This thesis is generally divided into 6 chapters; the first chapter is the introduction of this research study that explain the research background. Next, the problem statement, the questions of the research, the objectives of the research, the research contribution of this study, the scope of the research, and lastly, the organization of the thesis, are depicted.

Chapter 2 of the study looks into the related articles of the Healthcare Information System (HIS) and Collaboration HIS models, the fractal based system applications, the privacy preserving model, and the privacy preserving fractal healthcare information system model. Basically, this chapter reviews the importance of collaboration concerning this research study in order to achieve the research objectives.

Chapter 3 describe the methodology employed in this research study that start with research methodology flowchart. There are two main phases in this research study: (i) proposed the conceptual model e, and (ii) Development and evaluation the proposed model. Besides the using of instruments, and the methods of data collection. Followed by the implementation, testing, and evaluation of the proposed model.

Chapter 4 discusses the result and the analysis of the preliminary survey in order to validate the elements of the proposed model based on the literature review and pre-survey analysis that address the research questions.

Chapter 5 discussed the system development and present the results and the analysis evaluation of the PPFHIS prototype, system validation and testing as well as user manual for prototype system in order to evaluate the effectiveness of the system model. Finally, the conclusion of this study is presented in Chapter 6, which findings of the research, research contributions, strength and limitation of this research study, as well as recommendations for future works

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