Electronic Patient Referral System with Data Exchange and Fingerprint Patient Identification

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Abstract
Currently many healthcare systems process electronic patient referrals in Thailand. However, these systems suffer from two main obstacles. First, they can only process referrals from hospitals that use the same system. Consequently, medical staffs use such traditional methods as faxes or postal mail to transfer patient data. The second obstacle is the identification of patients when they cannot provide personal information by themselves. These obstacles hamper medical diagnoses. To cope with these obstacles, this paper proposes an electronic patient referral system with data exchange and fingerprint patient identification. From the initial phase of this research, we designed a cloud-based healthcare platform that provides such services as data exchange that allows the system to search for patient data using citizen IDs. In addition, this paper proposes an extended platform service: fingerprint identification. This service responds to citizen IDs from existing citizen fingerprint databases obtained during Thailand’s citizen registration process. By combining these two functions, we support medical staffs who are expected to operate the referral process faster and more conveniently and improve the quality of care for patients.

Keywords: patient referral, data exchange, fingerprints

Introduction

Recently, focus on the inequity of access to healthcare services between citizens in rural and urban areas has increased in many countries around the world including Thailand. Health care systems have developed in isolation because of the lack of unified data standards and technology. To address such problems, Thailand’s government sector started in 2008 a ten-year roadmap called Smarter Health and Smarter Living to stimulate the development of efficient healthcare services, including coordination among various healthcare providers, for better health and citizen well-being [1]. The roadmap introduced a blueprint to develop healthcare systems for various healthcare processes such as patient referrals, consultations, and emergency management.

Patient referrals in Thailand have changed from a paper-based to an electronic-based system. Currently, many hospital information systems electronically process patient referrals. However, this applies to referrals within departments in the same hospital or hospitals under identical corporations that use a system with unified standards and infrastructure. From a 2007 survey, over 32 different hospital information systems were deployed in 750 healthcare institutes in Thailand [2]. Although the top-five systems are used in approximately 56 percent of all the hospitals in the country, none has the capability to share or exchange data. This is the main obstacle for a patient referral process to obtain patient information when patients have to be referred to hospitals that use different systems. According to the blueprint, a system must be developed to support open standards, simple data conversion, and transfers regardless of different infrastructure.

One critical healthcare situation is emergency cases when patients need to be referred from one hospital to another that can handle a particular medical problem. Even though other hospitals obviously have competent doctors who can diagnose and give medical treatment, patient information must be reported to doctors in advance. Insufficient information may cause inadequate diagnoses or even medical errors that lead to disabilities or even patient deaths. The Journal of Patient Safety [3] reported that in the United States, from 210,000 to 440,000 patients die annually from medical errors. This was the third leading cause of death in 2011, according to the National Center for Health Statistics in the United States [4].

Apart from the above obstacle, patient identification is another main obstacle for diagnosis, especially in emergency cases. In such cases, patients are often unconscious and unable to provide personal information, complicating identification by medical personnel. Therefore, another identification method must be integrated to allow the system to identify patients regardless of their condition. Fingerprint was cited in the Health Insurance Portability and Accountability Act (HIPAA) by the U.S. Department of Health and Human Services (HHS) as an approved method to authenticate the identities of individuals [5]. The utilization of biometrics was proposed by
healthcare applications to protect and help manage medical records and to identify patients.

To cope with those obstacles, this paper proposes an improved design of an electronic patient referral system with data exchange and fingerprint patient identification. Data exchange is one service provided by the cloud-based healthcare platform proposed in the initial phase of this research [6] to enable data exchange among hospitals with different systems. We also proposed an extended feature of this platform, which is a fingerprint identification service used in patient referral systems in addition to the former method that uses citizen IDs. The improved design of electronic patient referral integrates these two services to provide a system that supports medical personnel to use fingerprints as input to identify patients and queries for patient data from other hospitals.

The rest of our paper is organized as follows. A literature survey is presented in Section II. The proposed design of our electronic patient referral system is described in Section III, including its overall system design and system framework. The last section concludes our paper and describes future works.

Literature Reviews

A. Proposed patient referral systems

N. Darcy et al. [7] proposed an electronic patient referral system called ZEPRS for women with complications during pregnancy. Their system, which must be used through a closed network, was the successful first perinatal referral system in Sub-Saharan Africa and became the first step toward developing a complete electronic medical record system. X. Huang et al. [8] proposed an electronic emergency referral document system that allows patient data to be transferred to other hospitals in a complete and timely fashion to doctors. Their prototype developed its own referral documents for across-enterprise document sharing.

B. Patient identification and access control in healthcare systems

1) Non-biometric methods

C. Turcu et al. [9] proposed an RFID-based system for emergency healthcare services that utilized RFID tags to store all vital health information on personal electronic record identity cards (PICs) in place of the former method that used paper-based medical cards. Its objective was to solve the need for an accurate and efficient way to transfer patient information between distinct providers when patients cannot provide identification information by themselves. The design included real-time locating systems (RTLS) to ensure safety and reduce losses. However, the cards still had to be handled carefully. Also, there were limitations of storage size and difficulty updating the information.

P. Mercini et al. [10] proposed a hospital healthcare and data management application using QR codes to facilitate the access of medical personnel to patient information, provide progress updates, directly send referrals, and instantly notify them of referrals using mobile devices. QR code technology can encode such data as texts, photos, and videos and store them as fixed or dynamic data.

2) Biometric methods

Y. N. Shin et al. [11] and R. Jose et al. [12] proposed healthcare system designs using fingerprints as a biometric access control for electronic patient records to eliminate such token-based access as passwords, electronic signatures, flash drives, smartphone tokens, etc. Both researches used fingerprint recognition to search for patient information from central databases. However, the first research’s system was designed to be used by medical personnel at hospitals, and the other research was designed to be used by patients in many cases, such as emergencies. The second research also performed experiments on response time testing. Without an optimization technique, the response time for data queries using fingerprints was acceptable for realistic situations: 19.8 seconds per 200,000 records in the database.

Surveys from R. Luis-Garc et al. [13] and International Biometric Group [5] about biometric identification systems concluded that fingerprint technology provides many benefits among various biometric devices, such as the identification of irises, voices, faces, and hand geometry. Based on the characterization criteria (i.e., accuracy, simple use, simple implementation, and cost), fingerprints were rated as highly accurate, easy to implement, somewhat easy to use, and medium-priced. Fingerprint technology is also the best-known biometric technique due to the uniqueness of fingerprints. In healthcare applications, fingerprint technology can be applied to protect and manage confidential medical records, identify patients, and protect the security of medical facilities and equipment. However, the challenges in implementing a system using fingerprints are registration requirements and storing the huge amount of fingerprint data.

From literature reviews, the limitations and suggestions to identify patients in the patient referral systems can be summarized as follows:

- **Limited environment of patient referral systems:** Since the currently proposed patient referral systems mainly focus on data exchange under closed networks or specific technology, they have difficulty in practical situations since most hospitals prefer to develop their own distinctive systems.

- **Lack of an efficient method for patient identification:** Patient referral needs an efficient method to enhance speed and convenience to quickly identify patients. Fingerprint technology has greater potential for
integration into systems than non-biometric

Therefore, this research proposes an electronic patient referral system that integrates data exchange services on cloud technology and fingerprint identification services to provide a more efficient system for Thailand.

Cloud-based Platform for Healthcare Services

Cloud-based platforms for healthcare services are the initial phase of this research. Various healthcare services allow registered healthcare institutes to integrate services into their healthcare applications. Data exchange services were primarily focused in this research as previously proposed [6]. A data exchange framework (Fig. 1) was designed to allow various healthcare applications to exchange data regardless of systems with different technology. The data model integrated many well-known standards, such as Health Level 7 (HL7) and 50 standard files. The data exchange mechanism enabled a system that uses the citizen IDs of patients as a master patient index (MPI) to submit requests for patient data through its platform. Then the platform became responsible for queries for patient data from other hospitals.

![Figure 1. Data exchange model](image)

Design of Electronic Patient Referral System

A. Overall system design

A cloud-based platform for healthcare service needs to have applications that utilize its services. An electronic patient referral system (Fig. 2) is the first proposed application that utilizes a data exchange service to obtain patient data from other hospitals. To request patient data, citizen IDs as patient identities must be used as input. In addition, we propose a new method to identify patients using their fingerprints because they are expected to be more useful for various cases such as emergencies. In addition, citizen fingerprints have already been recorded in local databases which belong to a government sector called the Department of Provincial Administration of Thailand. If our method is connected to the platform, it can be used as a reference for individuals in fingerprint patient identification services.

To realize patient identification using fingerprints, the following parts were added or modified as presented in Table 1.

| Related part                     | Added/modified part                  | Action |
|----------------------------------|--------------------------------------|--------|
| Input device                     | Fingerprint reader                   | Add    |
| Electronic patient referral system| Fingerprint acquisition module       | Add    |
| Cloud-based healthcare platform   | Fingerprint identification service    | Add    |
|                                  | Fingerprint database                 | Add    |
|                                  | Fingerprint matching module          | Add    |

With this improved design, users can enter either their citizen IDs or fingerprints as MPI or identity data and provide them to the system to request patient data.

B. Modular design

The modular design (Fig. 3) of our system is described in this section. Initially, we used modules related to data exchange. We added new modules to support the fingerprint identification service shown as orange modules (Fig. 3).

1) Electronic patient referral system
   - **Fingerprint Acquisition Module**: acquires fingerprints and temporarily stores them.
   - **Data Query Module**: acquires text input data as option for queries such as date intervals.
   - **Input Data Package Module**: combines two types of input (fingerprint images and text input) and submits packaged data to the platform.
   - **Local Data Query Module**: responds to query requests from the platform using the hospital’s local database.
   - **Data Display**: receives output from the Data Query Module and shows it in a web-based format.

2) Cloud-based healthcare platform
   - **Fingerprint identification service**: receives fingerprint data from the electronic patient referral system and forwards them to the server located at the government sector. The returned result as citizen IDs are forwarded to the data exchange services to process patient data requests.
   - **Patient data exchange service**: uses citizen IDs for queries for hospital locations that store patient data and sends requests to those hospitals. Once the requests are answered, the data are merged and returned to the hospital where the request is submitted.
3) Government sector
   Only one module, a fingerprint matching module, is responsible for matching the fingerprint input data with the existing fingerprint data of citizens and returns citizen IDs (if they exist).

4) Other hospital systems
   A local data query module automatically responds to the requests from the platform without a front-end system that is managed by users. The other hospital’s system can also be extended to more than only one hospital when patient records are stored in the local databases of many hospitals.

C. User workflow
   The user workflow (Fig. 4) is described to show how to use the electronic patient referral system by fingerprints as identity data. There are four steps for the user workflow. The details are described in sequence as follows:
   1. Enter input data.
      • Scan patient’s fingerprints.
      • Enter requirements for seeking the patient’s data.
   2. Submit query requests for specific patients.
   3. Get identified fingerprint results.
      • Case 1: Success
        System automatically sends a query for patient data. (Go to step 4)
      • Case 2: Fail
        Fingerprint quality is low and needs to be scanned again. (Go to step 2)
   4. Obtain patient data by reading the data displayed on the PC display.

D. Scenario-based example
   This scenario (Fig. 5) illustrates how an electronic patient referral system can utilize our new service (fingerprint identification) in an emergency case for a patient referral. While Jane was riding her bicycle one morning, she did not notice a car approaching from behind. She suddenly stopped and was hit by the car. She had already lost consciousness by the time that the rescue team arrived. She was admitted to the local city hospital closest to the accident. The doctor did a preliminary medical check and determined that her brain condition was serious and immediately ordered an operation. However, since Jane had never been to this hospital before, it had none of her records. Fortunately, the hospital was employing a new electronic patient referral system that can request patient data from other hospitals using fingerprints as identity information. The medical staff scanned Jane’s fingerprints and submitted a query request to the system, which sent a request to a cloud-based healthcare platform that searched for Jane’s data in all the hospitals connected to the platform. Soon all of Jane’s health information was displayed on the screen. The doctor analyzed the information, made a diagnosis, and gave her appropriate medical treatment and medication. Jane’s life was saved.
Discussion, Conclusion, and Future Works

We improved the design of our proposed electronic patient referral system by adding a fingerprint patient identification service to work with a data exchange service that identifies patients using only fingerprints and citizen IDs. This system has two advantages: (1) it supports faster and more convenient requests from medical staffs for patient data from other hospitals using only patient fingerprints, and (2) the referred patients receive better health care.

In conclusion, we proposed an improved design of an electronic patient referral system. Our proposed design includes fingerprint identification services to identify referred patients who cannot supply their own identity data by widely used biometric devices and fingerprint scanners to obtain fingerprints from patients. Our fingerprint identification service works with a data exchange service to search for patient data through a cloud-based healthcare platform.

Future work will implement and evaluate this system. Challenges include the reduction of time and improving the efficiency to identify individuals from a large database and to search and gather data from multiple sources. Further research will improve the user interface of our system on various different devices based on a usability principle.

Acknowledgement

The authors thank the National Electronic and Computer Technology Center (NECTEC) in Thailand for its financial support of this research.

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