Tele-Diagnosis System for Rural Thailand

C. Snae Namahoot and M. Brueckner

***Abstract*—**Thailand's health system is challenged by the rising number of patients and decreasing ratio of medical practitioners/patients, especially in rural areas. This may tempt inexperienced GPs to rush through the process of anamnesis with the risk of incorrect diagnosis. Patients have to travel far to the hospital and wait for a long time presenting their case. Many patients try to cure themselves with traditional Thai medicine. Many countries are making use of the Internet for medical information gathering, distribution and storage. Telemedicine applications are a relatively new field of study in Thailand; the infrastructure of ICT had hampered widespread use of the Internet for using medical information. With recent improvements made health and technology professionals can work out novel applications and systems to help advance telemedicine for the benefit of the people. Here we explore the use of telemedicine for people with health problems in rural areas in Thailand and present a Telemedicine Diagnosis System for Rural Thailand (TEDIST) for diagnosing certain conditions that people with Internet access can use to establish contact with Community Health Centers, e.g. by mobile phone. The system uses a Web-based input method for individual patients' symptoms, which are taken by an expert system for the analysis of conditions and appropriate diseases. The analysis harnesses a knowledge base and a backward chaining component to find out, which health professionals should be presented with the case. Doctors have the opportunity to exchange emails or chat with the patients they are responsible for or other specialists. Patients' data are then stored in a Personal Health Record.

***Keywords*—**Biomedical engineering, data acquisition, expert system, information management system, and information retrieval.

I. Introduction

TELEMEDICINE is a field of study which has attracted many researchers from various fields. The World Health Organization (WHO) adopted the following definition of telemedicine: "The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" [1].

In recent years a great number of studies have been published that focus on outreach services for rural areas around the world [2], [3], [4], [5]. Telemedical services help overcome distance barriers for patients residing in rural areas but can also be used for distance learning purposes. Patients from rural areas have to travel long time to present their conditions to a GP or specialist. Limited transport capacities may prevent them from getting to the Community Health Center or clinic. Such services need a capable and reliable Information and Communication Technology (ICT) infrastructure.

Thailand is building up a strong ICT infrastructure, which is currently projected to foster eGovernment, eCommerce, eEducation, eIndustry and eSociety. Experts recommend include eHealth (or telemedicine) as a sixth component of the framework ICT 2020 together with mechanisms for capacity building of eHealth professionals and experts [2]. Other requirements for an effective eHealth provision in Thailand are the installation of a national eHealth governing body and the development of national standards for the operation and distribution of health information via eHealth services. The Telemedicine Diagnosis System for Rural Thailand (TEDIST), which is described in the remainder of this paper, acts as a component for education and operation for telemedicine and ehealth applications.

Regarding standards, the ICD10-TM (International Classification of Diseases Version 10 - Thai Modification) and the ICD9-CM (Clinical Modification) have been introduced at the national level for coding diagnoses and health service interventions, respectively. Whereas the patients' administrative data (used for health insurance, administration and reporting) can be distributed among nearly all of the health facilities in Thailand, the clinical data are collected on paper and in computerized formats, but the capability of exchanging these data is very limited [2]. Moreover, for the effective exchange of clinical data LOINC[1] has been considered as a potential choice.

II. Related Work

A number of studies have explored the advantages and disadvantages of telemedical applications worldwide (see, e.g. [3], [4]). Consultation systems using the Internet have recently received attraction, but they are mostly used as a tool serving the medical professionals and not the patients [6]. Web services are a feasible way to implement such a system based, for example, on the Simple Object Access Protocol (SOAP)[2]. They allow a Web browser to efficiently use structured text data with a Web service. The potential benefits and deficiencies of telemedicine have also been studied. In [7] Verhoeven et al. undertook a systematic review of the

C. Snae Namahoot is with the Department of Computer Science and Information Technology, Faculty of Science, Naresuan University, Phitsanulok, 65000 Thailand (phone: +66 55- 963223; fax: +66 55-261025; e-mail: chakkrits@ nu.ac.th).

M. Brueckner is with the Department of Computer Science and Information Technology, Faculty of Science, Naresuan University, Phitsanulok, 65000 Thailand (phone: +66 55- 963263; fax: +66 55-261025; e-mail: michaelb@ nu.ac.th).

[1] http://loinc.org

[2] http://www.w3.org/TR/soap/

practicability and cost-effectiveness of telemedicine for such chronic diseases as diabetes. Their results suggest that teleconsultation is a useful and cost-effective way of delivering health care services; they point out, however, that "interactive systems should be developed that integrate monitoring and personalized feedback functions" to further the contribution of technology to health care. And telemedicine is also accepted by patients, as was shown in [8].

Relating ear, nose and throat (ENT) conditions telemedicine has been explored as well, e.g. in [9], where strengths and weaknesses of interactive and delayed consultations were analyzed with 45 adult patients. The study showed that both methods lead to relative accurate clinical consultations, whereby the main applications were seen in subspecialty consultations, second opinions and resident education.

As the first site developed in Thailand with direct patient contact and communications, the Ao Lak telemedicine system illustrates improved efficiency, cost-effectiveness, and logistics, which can be useful in rural health care delivery and for efficient geographic distribution of resources. Integrated POCT (Point-of-Care-Testing, e.g., cardiac biomarkers) would help improve district and province referral systems [10].

Some of the published systems offer computer support for taking the anamnesis; however, because those systems are not Web-based, they are of no use for patients in rural areas.

III. Use Case and Scenario

The Community Health Centers of Thailand are small scale clinics that have to handle patients ranging in age from newborn to geriatric. The patients present minor illness up to life-threatening conditions, which makes it very difficult to predict the period of time the average patient will take on a day. The usual result is that the health professionals fall behind schedule. Since the 1980s efforts have been made to use the patients' waiting time for entering their signs and symptoms into a computer file. Sitting in the waiting room time would seem to be less dragging for waiting patients, if they had the opportunity to enter their personal data in the computer. As a more recent way to present their conditions to health professionals the Internet has been used in many countries. In this case, the patient can use a Human-Computer Interface (HCI) that comprises two key components: (1) medical history and (2) medical decision making. These components will be explored in more detail focusing on problems with ears, nose and throat, eyes, and the respiratory system.

(1) As for the patient's medical history it is analyzed what the chief complaint is, and the history of the present illness is reviewed, e.g. the location, duration, severity and associated signs and symptoms. According to the patient's answers the system will request information from them to come to a medical decision. For a patient presenting a cough the system would ask for how long this condition had been present, whether it were there at night or all day long, whether it seemed to occur in spasms or episodes of multiple cough, and whether it brought up sputum from the deep in their chests. The system would also ask about the use of tobacco and contacts with birds.

(2) According to the presented conditions the system and answers to the questions, a set of potential assessments is created, which might consist of one or more entries. This gives a first assessment for the clinicians to work on, and together with the protocol of step (1) they can examine the case further and in more detail.

IV. TEDIST System

The system comprises a knowledge base, which has been built by setting up rules from the literature ([11]) and extracting knowledge of specialists through interviews. Patients are requested to access a Web site and login. The system then asks for signs and symptoms, uses the responses to ask further questions and finally comes to a diagnosis (or to a list of possible ones) with the help of the knowledge base. After getting the diagnosis the system forwards the patient's data to an appropriate health professional. Doctors can answer by email or chat directly if the patient is available online. There is also a chat room for health professionals, who can request help from specialists. Patient data are stored in a Personal Health Record (PHR).

TEDIST consists of three levels: a client, an application server, and a Database Management System (DBMS). Web services are used to connect a client (Web browser) with the database server, which uses MySQL Server 4.0.

A. Requirements

Tele-anamnesis with TEDIST applies the well-known practices of obtaining subjective patient data by asking specific and clear (i.e. easy to understand) questions, which the patient answers. TEDIST uses yes/no questions and two levels of vocabulary: medical terms in the knowledge base and common terms on the user interface. Since TEDIST is designed for rural Thailand, the UI language is Thai.

After the user/patient has logged in to TEDIST the system knows their full name, sex, marital status, blood group, address, phone numbers, date and place of birth, and occupation. First, TEDIST asks if anything has changed, and if so, asks for changing data in the profile accordingly. Also, with login TEDIST has the patient's past medical history available, e.g. childhood illnesses, accidents, surgeries, blood transfusions, serious and chronic diseases, immunization, and allergies. Questions have been asked on these during the registration process. Moreover, the complete lab data for the patient are available to the system, including blood pressure, pulse rate, weight (with BMI derived), and body temperature are available and can be used by TEDIST.

Non-functional requirements cover the usability of the system for both patients and doctors. This builds a vital part of the system design, since the anamnesis process requests a comfortable atmosphere. Usability for teleanamnesis systems comprises clarity and understandability of the questions asked by the system, ease of access to the functions and readability of texts in questions, answers and messages. Additionally, requirements for secure transfer of medical data over the

Internet were considered for the design and implementation of TEDIST.

B. Basic System Specification

- Storage of various diseases relating the respiratory system and diseases related to ear, nose, throat, and eye.
- System design by asking the symptoms of the patient and take answers as input and analyze each answer using forward chaining neural network, a rule-based system with a decision tree.

The user interface comprises three levels, which are organized according to user roles:

(1) patients/users –fill out forms with all necessary details

- System will have a complete history of the patient before the diagnosis of the system. Users/patients can choose a username and a password for accessing the system.
- System generates questions for the diagnosis of common ENT diseases and transmits data to the doctor for diagnosis and recheck.
- System allows the patients to be able to chat with the doctor directly which can be online for medical questions

(2) medical professionals, e.g. doctors, nurses, and their assistants

- System allows doctors to detect and diagnose the disease, the patient was sent via the system.
- System enables physicians/doctors to deliver the decision and recommendation of treatment to the patient.
- System allows doctors to talk to patients at home using a chat program.

(3) administrators can add, delete and modify information about diseases which can keep them up-to-date.

The database tables consist of patient information, the medical information, the diseases which is about the details of diseases and various treatments etc.

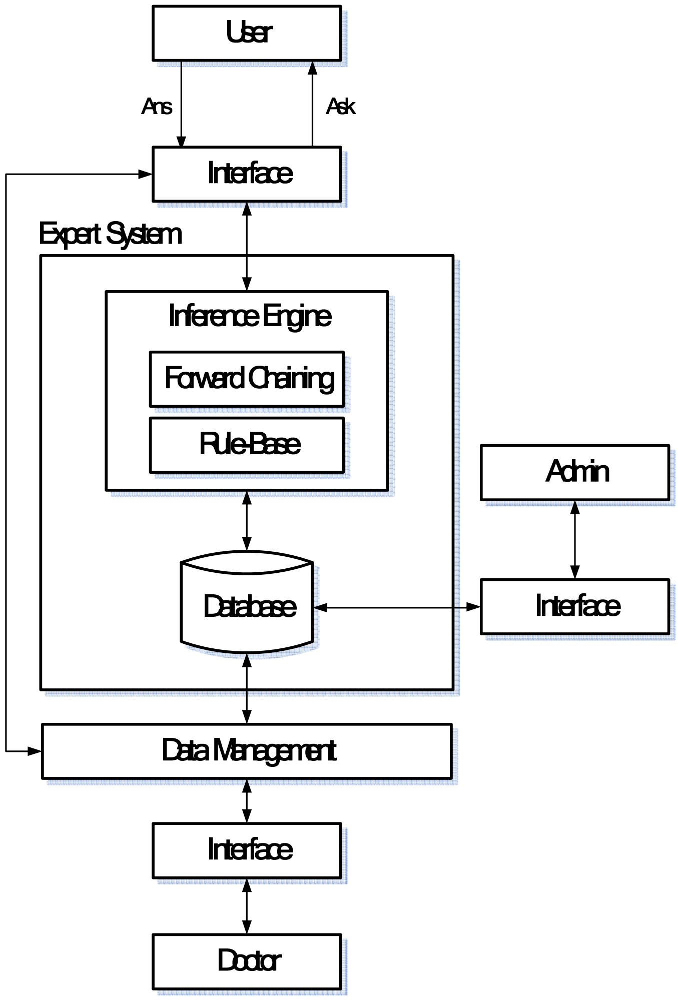

Fig. 1 System Overview

Data Preparation by collecting information about the diseases which contain important information such as the name of the disease, symptoms, treatment, complications and recommendations etc.

The expert system consists of three parts.

1) The user interface is designed to enable users to understand the system simple to use program although have no skill before. The user interface provides description of the application process. The design of the system can tell the user detailed information about the disease and how to take treatments which consists of 2 main parts:

- The user can receive patient symptoms, show the options to the patient, show the patient selection and summarize this knowledge to patient.
- A doctor can show the data of each patient and receive the diagnosis of medical information from the system.

2) The process is designed to manage questions to patients and display all possible diagnosis and treatment results from patient conditions.

3) The database is designed using MySQL database which is compatible with PHP language and can be retrieved easily and

quickly. The database has been divided into the following tables.

- All user data (users).
- The patient data (user_system).
- Medical data (doctor_system).
- The information system administrator. (admin_system).
- Schedule disease data (disease).
- Schedule disease information to get an answer from the user. (disease_forward).
- The introduction of a medical information. (doctor_comment).
- The detailed medical information. (doctor_diseaseinfo).
- Schedule for the diagnosis of patients. (user_information).
- The more detailed diagnosis of the patient. (user_diseaseinfo).
- The information to answer the questions of patients. (forward_question).

Fig. 2 shows the components of the system, which comprises a rule-base and an inference engine with forward and backward chaining as described in [12], [13], [14].

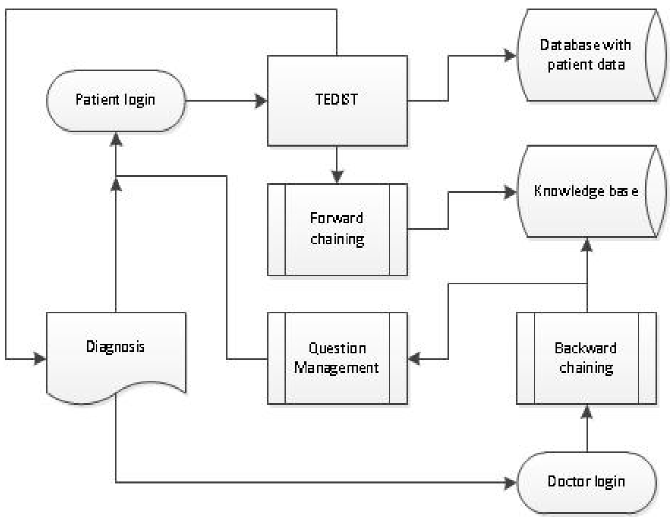

Fig. 2 System overview of TEDIST

Firstly, the chief complaint is specified by the patient/user to TEDIST. The system then allocates the properties of diseases related to the chief complaint and prepares for the questioning task with the help of the knowledge base; for example, the system asks which chief complaint the user has: ears, eyes, noses and mouths. After that the user/patient answers the questions of the system, which finally comes to a diagnosis. With each question the assessment part of the system evaluates the value of the answer for the overall investigation process.

The components of the system framework comprise:

- Question Management is used for the management of knowledge about diseases, (in this system concentrates only on ears, eyes, noses, and mouths) and the provision of yes/no questions for users/patients
- The disease clustering technique is used to group diseases, for example, diseases that show similar or identical symptoms. In the system framework (1) characteristics of symptoms are sorted and then related by classification; clustering stores any types of diseases and some related symptoms, (2) this will help to pose useful questions that the user/patient has to answer, (3) supply fast access to required information
- Inference engine tools: forward chaining (data driven) is used for finding the answer of a disease that the user is having while using the system. The tool considers/examines all symptoms and data from the answers provided by patients, e.g., after patients have chosen type of diseases that they are having and the system asks patients about symptoms of diseases. The patients have to provide correct answers as yes or no, so that the system can get back with other questions to follow in accordance with previous patient answers and try to diagnosis the correct disease within a minimal number of questions.
- Backward chaining is used by doctors to recheck and trace the answers to the questions, e.g. if the correct answer is chronic bronchitis, then the system rechecks all questions and answers that the patients have provided. In this way, the doctors can evaluate correct diagnosis and suggest treatment or further health checks. An answer revision process is used to display questions that patients have answered during the session.

The doctors can assess patients' symptoms, e.g. by diagnosis, understanding, analysis and give treatments and advice to patients after assessment.

Regarding the non-functional requirements stated above, we introduced a way to zoom in or out of the Web pages, so that the users (patients and doctors) questions, answers and messages easily. Nowadays, user interfaces can be designed and implemented with a wealth of technical opportunities, which may lead to overshadow the important points. For patients, the user interface must be simple and ease of useand rich information to keep useful attention. The user interface is based on the "keep it simple, stupid" (KISS) principle, so that it is easy to use and does not need an instructional process.

V. Results and Discussion

Regarding the test of TEDIST two different experiments were undertaken: (1) the system test, which was performed with a group of 25 patients, (2) the continuous test of the user interface over the development process, where 15 people with varying computer knowledge used the system to find flaws in different steps of the development process.

(1) For the system test 25 patients with ear, nose and mouth conditions presented their cases to a human doctor, who came to a diagnosis by employing their usual anamnesis and diagnose techniques. Additionally, the patients used TEDIST to come to a diagnosis. A summary of the test patients' characteristics is shown in Table I. The average age of patients was 37 years with 12 male and 13 female participants of the

system test group. Chief complaints were nose (9 patients), eye (7 patients), throat (6 patients) and ear (3 patients). Table 1 lists the main data about the patients that undertook the system test. The computer knowledge was assessed by the patients themselves on a Likert scale before starting the system test and found to be with 2.96 slightly above average. TEDIST came to a diagnosis after slightly more than six questions asked and answered.

The result of TEDIST (diagnosis) was rechecked by three doctors with the help of a backward chaining process, which made clear how the system derived each diagnosis, cf. examples below. The doctors not only checked the questions that TEDIST posed to the patients and their answers but also undertook a live anamnesis with the patients to find out the diagnosis in the traditional way. The results show a level of consistency between TEDIST and doctors' diagnosis at 78%, which is quite high given that the system is at a prototype stage.

(2) Test of the user interface (UI) was performed in a continuous process during the software development and involved 15 users to uncover usability problems of TEDIST. In each step five different users with computing background were obliged to check the user interface for flaws and errors. They used the user interface for patients (in each step 3 power users without medical background) and for doctors (in each case 2 medical students). We checked the user interface in this way first at the design process, then at the prototype and at last before the system test (see above). The five users at each test step were different persons. Among the group that tested the user interface before the system test were three users with visual impairments to check for readability of all texts accessible to the users and doctors.

TABLE I
DATA OF SYSTEM TEST PARTICIPANTS

Patient	age	complaint	# question	C-Know
1	17	eye	7	4
2	22	nose	5	3
3	34	nose	5	4
4	28	throat	6	2
5	55	eye	7	4
6	48	ear	4	1
7	45	nose	5	4
8	29	throat	7	3
9	24	nose	8	2
10	43	ear	6	3
11	61	nose	8	4
12	22	throat	6	5
13	27	eye	4	2
14	42	ear	7	3
15	39	nose	6	4
16	55	throat	8	2
17	45	eye	6	3
18	36	eye	7	2
19	41	nose	5	1
20	60	throat	4	4
21	40	eye	6	3
22	20	nose	5	2
23	15	nose	4	3
24	44	throat	7	4
25	33	eye	8	2
average	**37**		**6,04**	**2,96**

Example of chronic bronchitis diagnosis (Fig. 3)

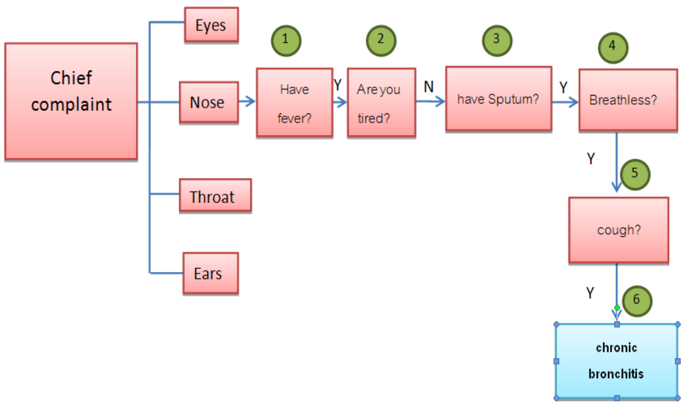

Fig. 3 Diagnosis of chief complaints

Patient's main complaint is the nose. In this case, the first question asked is "Is your body temperature above 37 °C?", since this symptom has the highest frequency relating conditions of the respiratory system ("nose"). The patient answers "yes", so the system looks into the frequency table and keeps all diseases that have symptom of fever and then provides the next question based on the highest frequency of symptoms that occur within the range of related diseases. In this case "Are you tired?" The patient answers "no", after which the system eliminates diseases from the related disease list and looks for remaining diseases that show fever with the highest frequency of symptoms. It then generates the question "Do you have throat swap (sputum)?". The patient answers "yes", and the system carries on choosing appropriate questions, in this case "Do you breathe properly (or are you breathless)?" and "Do you cough?", which the patient answers "yes", so the system's diagnosis is that this patient has a chronic bronchitis.

VI. Conclusions and Further Work

In this paper we presented a design-and-create research for the Web-based telemedicine system TEDIST (Tele-DIagnosis System for rural Thailand). The system has been carefully designed to help user/patients with ear, nose, throat and eye conditions, as well as doctors save time during the anamnesis process. TEDIST can be used as an outbound diagnosis system that user/patients can use from their homes and as an inbound diagnosis system to help assign a patient presenting to a specialist in the medical institution. The user interface has been kept as simple as possible with the result that after intensive usability tests the user/patients found no flaws when using it. The system test with patients presenting conditions was limited, on the other hand, to 25 patients, which might not be enough to create trust in the functionality of TEDIST. Nevertheless, the test results are encouraging, especially conceding the fact that TEDIST is at a prototype stage. Therefore, we plan to extend the features of the system to diagnose other parts of the body system, e.g. neck and skin. For further tests (with a higher number of patients) we need an automatic way to protocol the live anamnesis dialog and compare it to teleanamnesis dialogs.

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C. Snae Namahoot is currently a lecturer and an Assistant Professor at the Faculty of Science, Naresuan University, Phitsanulok, Thailand, and the head of the research group SIRM (Software Innovation and Management). He received a Ph.D. in computer science from University of Liverpool, Liverpool, England, 2006. M.Sc. in computer science, University of Newcastle upon Tyne, Newcastle, England, 1999. B.Sc. in mathematics, Naresuan University, Phisanulok, Thailand, 1995.

His research interests include semantic web applications, ontologies, embedded system, natural language processing, expert and intelligent system, and Software Engineering. He received a research award from the Ministry of Information and Communication Technology in 2010, and in 2008 he earned an award for outstanding doctoral dissertation from the National Research Council of Thailand.

M. Brückner is currently a lecturer at the Faculty of Science, Naresuan University, Phitsanulok, Thailand, and deputy head of the research group SIRM (Software Innovation and Management).

He received a diploma in physics (Dipl. Phys.) from the Technical University Munich, Germany, and worked on simulation software for physical processes, Computer-Aided Design, project management and software quality assurance.

He is involved in the field of knowledge and information management for more than two decades. His current research interests are Semantic Web applications, telemedicine service, ontologies, natural language processing, and intelligent systems.