Development of Automated Triage System for Emergency Medical Service

H.A. Chong
Dept. of Electrical, Electronic, and Systems Engineering
Faculty of Engineering and Built Environment
Universiti Kebangsaan Malaysia
Bangi, Malaysia
e-mail: haoannchong@gmail.com

K. B. Gan
Dept. of Electrical, Electronic, and Systems Engineering
Faculty of Engineering and Built Environment
Universiti Kebangsaan Malaysia
Bangi, Malaysia
e-mail: gankokbeng@ukm.edu.my

Abstract—**Emergency department is the frontline and critical service of a hospital which provides wide ranges of medical services which includes diagnostic, resuscitation and stabilization components to save life. Triage is a process that assists assistant medical officer to justify condition of patient and arrange appropriate treatment for them. According to The Policy of Emergency Medicine and Trauma Service of Malaysia, all patients who accessing to any treatment in emergency department shall proceed to triage. However, the ongoing crowding of emergency department has led to calls for improvement of triage system to facilitate effectiveness of this process. To overcome this problem, a computerized triage system known as Automated Triage System was developed to perform triage within time limitation for each patient and consistent triage decision. Automated triage system could improve quality of service and reduce costs due to misappropriate of resources. The developed system consists of biomedical modules, graphical user interface (GUI) using Microsoft Visual Studio and triage decision making algorithm. This system acquires vital signs, syndrome and chief complaint from patient. The acquired data will be analyzed using triage decision making algorithm and triage level of a patient will be reported instantly. All information and patient records will be stored in database for future reference. Finally, an automated triage system has been designed and developed to assists assistant medical officer to perform triage assessment in Emergency Room. This system can provide accurate and specific triage output compared to the one done by assistant medical officer. The average time taken to perform the triage assessment using this system is around 6 minutes.**

Keywords— Automated triage system; emergency medical service; graphical user interface

I. INTRODUCTION

Triage is normally used in emergency department to screen patients before proceeding to any treatment. This process is performed by trained and experienced assistant medical officer. When patient is presented at triage counter, assistant medical officer will obtain patient vital signs and chief complaints and record them in triage evaluation sheet. Example of evaluation sheet is shown in Fig. 1. Result of triage is analyzed and judged by assistant medical officer to categorize patients into different triage categories. Triage should complete within two to five minutes [1].

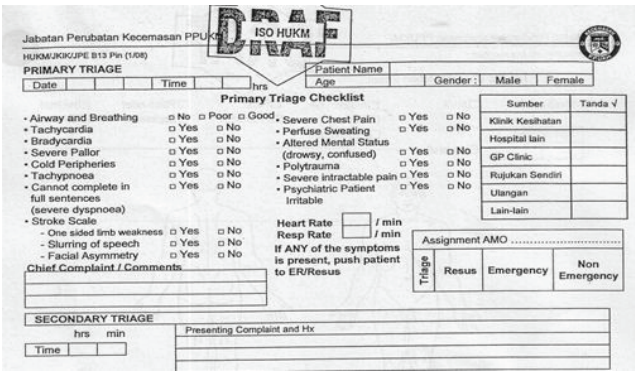

Fig. 1. Evaluation sheets for triage

Universiti Kebangsaan Malaysia Medical Center (UKMMC) has developed a triage assessment scale known as Objective Primary Triage Scale (OPTS). OPTS is a locally developed system based on Emergency Severity Index (ESI) [2-4]. This triage system consists of two models, known as primary triage and secondary triage. These models will categorize patient into suitable triage category. The inputs for this system are vital signs, syndrome and chief complaint. Inputs for primary triage model and secondary triage model are different (TABLE 1). Syndromes collected in primary triage assessment are patients' general appearance and the syndromes collected in secondary triage assessment are the known cases and history of patients.

TABLE I. INPUTS FOR PRIMARY AND SECONDARY TRIAGE

Primary triage input	Secondary triage input
Age	Age
Gender	Gender
Chief complaint	Chief complaint
Airway & Breathing	Heart disease
Tachycardia	Hypertension
Bradycardia	Diabetes
Severe pallor	Epilepsy
Cold peripheries	Cerebrovascular accident
Tachypnoea	Asthma
Dyspnoea	Chronic kidney disease
One sided weak limb weakness	Hepatitis
Slurring of speech	Gastritis

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Severe chest pain	Benign prostate hyperplasia
Perfuse sweating	Allergic
Altered mental status	Migraine
Polytrauma	Cancer
Severe intractable pain	Pulse rate
Psychiatric	Blood pressure
Respiration rate	Body temperature
Pulse rate	Respiration rate
	SpO_2

Triage decision is a factor that influenced the health outcome of a patient. It is often complex task and made under uncertain conditions because it is involving in dynamic information flow and variations in emergency case. Existing triage system is highly depending on individual expertise and experience [5-6]. To improve the consistency and quality of triage, an automated triage system is needed [7-8].

An intelligent processing model [3-4] has been developed to serve as triage decision support system triage system. The biomedical text medical data were extracted from the OPTS data sheet from Emergency Department in UKMMC. A new enhanced random forest has been developed by using randomized resampling. Random forest usually reduces the variance without bias change. By introducing randomized resampling as pre-processing step to the random forest, this reduces bias and then reduces the OOB error. This new enhanced random forest with 300% randomized resampling ratio has accuracy of 0.98 and 0.02 OOB error [3-4].

In UKMMC, triage process requires an assistant medical officer to fill-in the patient information and details such as vital signs, syndrome and chief complaint on evaluation sheets manually. All the recorded information needs to be documented, processed and transferred into computer database manually. Process of transferring these data may lead to problem caused by human error such as missing of data and mistakes of information.

During triage process, assistant medical officer measures and records vital signs of patient manually. Manual measurement and recording are prone to human error, time consuming. Therefore, an automated vital signs recording is necessary in triage system.

In this paper, an automated triage system is proposed to automate the vital signs and chief complaint data acquisition. The data will be processed by triage decision making algorithm [3-4] to give an accurate and consistent decision in short period of time.

II. Methodology

The proposed automated triage system consists of e-Health Sensor Platform and graphical user interface (GUI) developed using Microsoft Visual Studio 2015.The acquired inputs are patient's vital signs, syndromes, and chief complaint. These data will be processed by a triage decision making algorithm embedded in the GUI to give triage outcome.

The triage decision making algorithm was developed in Matlab using signal processing and machine learning techniques known as Random Forest algorithm. The algorithm is compiled and deployed in this system. The data will be recorded into MYSQL database for future reference.

The inputs for this system are vital signs, syndrome, and chief complaint. Vital signs are collected via biomedical modules and sensors .Meanwhile, the syndromes and chief complaint are the selection by assistant medical officer from the list of syndrome and chief complaints listed in GUI. Inputs from patient will saved into temporary text file as variables that will be fed into triage decision making algorithm.

The vital signs were acquired through multiple sensors from patient using e-Health Kit V2.0 and Arduino platform (Fig. 2). The blood pressure was acquired using sphygmomanometer. This module contains a cuff and an external monitor. It is an oscillatory device which used to measure pulse rate and blood pressure. It gives digital reading when the vibrations in the arterial wall detected due to principle of blood flowing through an artery between systolic and diastolic. Readings will save inside module.

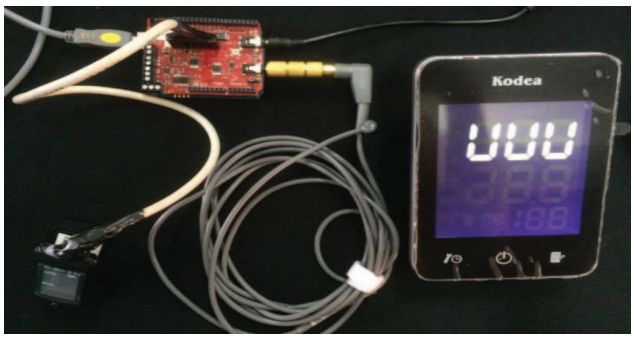

Fig. 2. Hardware for vital sign measurement

Pulse oximeter measures oxygen saturation in blood vessel. This device emits light at two wavelengths where the difference of these two wavelengths indicates the concentration of oxyhemoglobin inside blood vessel. Monitor will display the percentage of oxygen saturation in blood vessel and heart rate. Temperature sensor used in this system is a stainless steel temperature metal probe that can measure body temperature directly.

These sensors were integrated in e-Health Kit V2.0 and the data was processed by Arduino Uno. The Aduino platform communicates and sends the acquired data to the GUI via serial communication. The acquired vital signs values are displayed in GUI, save into temporary file and local database as shown in Fig. 3.

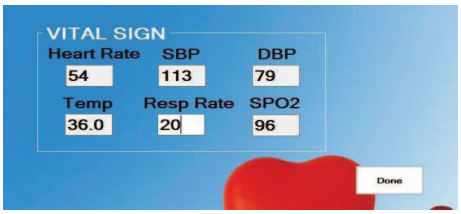

Fig. 3 Vital signs acquisition using GUI via Arduino and e-Health Kit V2.0

Syndromes and chief complaint will be collected manually by assistant medical officer. The data collection process will be done by selecting the appropriate syndrome and chief complaint listed in GUI. The GUI of this system was developed in Windows Form Application using Windows Visual Studio 2015. The selected syndromes and chief complaint will be saved in temporary text file and local database.

The triage decision making algorithm analyzed the input variables obtained from temporary text files and predicts the triage category as shown in Table II. The output of this system will be saved in text file format and display in GUI to notify users as shown in Fig. 4.

TABLE II. CLASSES OF TRIAGE OUTPUT AND DESCRIPTION

Triage output	Description
Zero	Resuscitation
One	Emergency cases (Patient condition is unstable)
Two	Emergency cases (Patient condition is stable)
Three	Urgent cases (Treatment must perform within 24 hours)
Four	Non-emergency case
Five	Patient with age above 65 years old

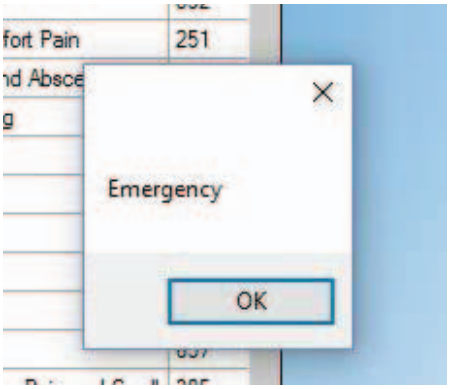

Fig. 4 Decision making algorithm predicted a patient health condition is in emergency condition

The other function of this triage system is to view the history of the patient assessment record. The system can display time of performed triage, input of vital signs, syndromes and chief complaint (Fig. 5). The patient record is searchable based on their identification card number. Only one patient record can be searched at one time. The data can be printed for reference purpose.

timestamp	year	chiefcomplaint	airwaynbreathing
5/7/2016 9:58:54 PM	2016	107	1
5/7/2016 10:35:54 PM	2016	51	0
5/8/2016 12:06:02 AM	2016	107	0
5/8/2016 2:39:17 AM	2016	107	0
5/8/2016 2:49:04 AM	2016	107	0
5/8/2016 2:54:12 AM	2016	651	0
5/8/2016 2:58:39 AM	2016	15	0

Fig. 5 Patient assessment records

III. RESULTS AND DISCUSSIONS

The automated triage system was successfully developed and tested for its functionality (Fig. 6).

Fig. 6 Developed automated triage assessment system

To evaluate the accuracy and specificity of developed triage system, 30 sets of real case samples obtained from UKMMC were tested. The triage assessments have been done by assistant medical officer in UKMMC.

Table III and IV show that the developed triage system can provide accurate and specific triage output compared to manual triage performed by assistant medical officer. The average time taken for the triage system is around 6 minutes.

TABLE III. SAMPLE TEST OF PRIMARY TRIAGE ASSESSMENT

Triage output from sample	Predicted Triage Output			
	One	*Two*	*Three*
One	5	0	0
Two	0	23	0
Three	0	0	2

TABLE IV. SAMPLE TEST OF SECONDARY TRIAGE ASSESSMENT

Triage output from sample	Predicted Triage Output				
	One	*Two*	*Three*	*Four*	*Five*
One	2	0	0	0	0
Two	0	5	0	0	0
Three	0	0	8	0	0
Four	0	0	0	12	0
Five	0	0	0	0	3

IV. CONCLUSION

An automated triage system has been designed and works with developed triage decision support system to assists assistant medical officer to perform triage assessment in Emergency Room. The average time taken to perform the triage assessment using ATS is around 6 minutes which is almost the same with time taken for manual triage.

The research has tested with 30 sets of database obtained from Emergency Department of UKMMC. The result from ATS and manual triage is the same which show that ATS able to sort out the patient accurately. Beside that, this system is able to store every patient's record in database. It allows medical officer search for patient's health history and performs patient's personal health care analysis.

There are few recommendations for future work to be considered. Firstly, the respiration rate is taken manually in this developed system. Therefore, a device to measure respiration rate is recommended to fulfill the term of automated triage system. Next, the current developed system save the data into local database. Cloud service is recommended so that the database can be shared and used in other departments. Finally, it is recommended to improve the triage decision making algorithm so that the automated triage system able to give result in shorter time.

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