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Design and Implementation of an Automatic Emergency Management System

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Abstract: In this study, we have presented design and implementation of an Automatic Emergency Management System (AEMS) which can be used by hospitals for preliminary diagnosis of a patient's condition in the emergency department. The AEMS consists of both hardware and software: the hardware has been designed to replace some medical equipment and software has been developed to compensate for human thinking and human experience. This system is expected to assist the emergency department staff in assigning priority levels to the patients and should bring about a quicker and more accurate patient's assessment.

Key words: Artificial intelligence, expert systems, medical sensors, vital signs, hospital emergency

INTRODUCTION

The need for doing things quickly (and perhaps, more efficiently also) forced the human being to invent machines which work faster and are more accurate than him in carrying out the job at hand. Since the emergency department at the hospital is usually very crowded which results in delay in the patient's diagnosis and treatment, efficient and speedy assessment of the patient's condition has become a necessity. An Automatic Emergency Management System (AEMS), which can be used to achieve this objective, is the solution to this problem.

Like any computer engineering applications, the work was divided into two parts: Hardware and Software. The hardware consists of the sensors that will be used to measure the patient's vital signs (temperature, pulse rate, respiration and blood pressure) and a data-logger which accepts the signals from the sensors and feed them into the computer. The software, which has a user-friendly interface, decides on the severity of the patient's condition based on three main factors: The acquired data (Vital Signs), Chief Complaints and Risk Factors to assign him/her one of five priority levels: Immediate, Very Urgent, Urgent, Standard, or Non Urgent (Deferrable).

The tasks were to design the diagnostic system software, to figure out the techniques of how to attach the sensors and their associated accessories to the patient, to interface the sensors, data logger and other hardware components to the software and in addition to implementing a great deal of engineering practices (e.g., cost, reliability, complexity, literature survey), a thorough medical investigation to be carried out within the emergency department of the SQU Hospital.

PROBLEM FORMULATION

The main difference between the emergency department and any other department in a hospital is that they need to give the patients priority levels, then each patient will wait a maximum of *n* min depending on the severity of his case, so the problem here is how can the staff of the emergency department decides who should see a doctor first.

What they do first is to take the patient vital signs readings, then they have this long charts and diagrams of the most common chief complaints, so they look at the patient and ask him questions (they call them discriminators) to see in which category does he/she fits and finally they consider what ever additional risk factors he/she could have, such as: being diabetic, very old age, smoking, etc.

This process is called Triage which is a French word, meaning to sort, so no matter who is performing it, a doctor (general practitioner) or a nurse and no matter how much experience does he/she has, they still have to look at three main things at the same time: 1.The Vital Signs 2.The Chief Complaints 3.The Risk factors.

The triage scale: Triage is the medical term for the main job of our system, which is assigning priority levels to the patients[1]. The time interval between arrival and first

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Table 1: Five priority levels of emergency patient's diagnosis

Priority level	Name	Color code	Maximum wait time (min)
1	Immediate	Red	0
2	Very urgent	Orange	10
3	Urgent	Yellow	60
4	Standard	Green	120
5	Deferrable	Blue	240

attention by a practitioner (this may be a doctor or a nurse) to be able to institute treatment will be decided according to the priority level as it's shown in Table 1.

- Immediate (Red category): Patient in need of immediate treatment for the preservation of life. All patients to be seen on arrival. These patients would usually be met by a team 'stand by' after prior notification by the ambulance service.
- Very Urgent (Orange category): Seriously ill or injured patients whose lives are not in immediate danger. All these patients should be seen within ten min of arrival.
- Urgent (Yellow category): Patient with serious problems, but apparently stable condition. All these patients should be seen within 60 min of arrival.
- Standard (Green category): Standard emergency cases without immediate danger or distress. The aim should be for these patients to be seen within 120 minu. The percentage which can be seen within this time depends on resources available. For example, few departments in the UK can achieve rates above 80%.
- Non-urgent Deferrable (Blue category): Patients whose conditions are not true accidents or emergencies. If these patients are to be treated, they should not have to wait more than 240 min and it will depend on resources available. Patient in this category may be redirected to more appropriate facilities.

Chief complaints: Let's take an example of a famous complaint, abdominal pain: It is a common cause of surgical emergencies. To detect the cause of this pain, several discriminators (questions) are used to ensure that the patient is correctly diagnosed in a limited period of time. In particular, discriminators are included to ensure that patients with moderate and severe bleeding and those with signs of irritation are given sufficiently high categorization. For example, as shown in Fig. 1, the first question they ask the patient (and ask themselves by looking at him/her) is whether airway of the patient is compromised or not. If the answer is yes (meaning that the patient cannot breath properly) then he/she will be categorized as Red (Immediate) directly and if the answer is no then they will have to look at other discriminators.

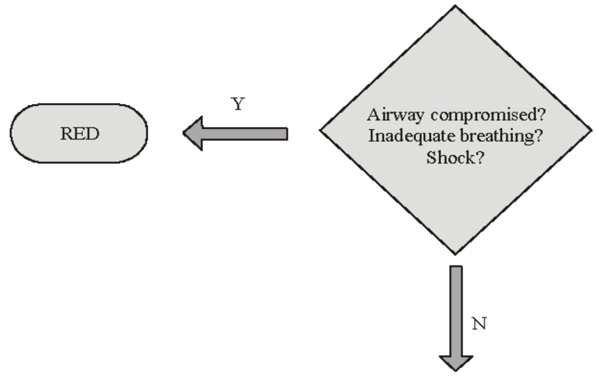

Fig. 1: Flowchart of a discriminator to triage abdominal pain

If the answers of all the discriminators, asked by the doctor or nurse to diagnose abdominal pain are no, then the emergency staff will reach the conclusion that the patient falls in the least priority category which is Blue (Deferrable). Depending upon yes or no answers found while asking the discriminators for abdominal pain, the patient can be categorized in Orange (Very Urgent), Yellow (Urgent) or Green (Standard) and then appropriate steps can be taken to alleviate the patient's condition.

Vital signs: The measurement of vital signs (blood pressure, temperature, respiration and pulse rate) is an important component of patient assessment in the emergency department. Vital signs should be used along with the patient history, chief complaints and physical examination to determine the level of emergency. These measurements can be affected by some parameters that should be taken into account such as the patient previous medical record, environmental condition such as room temperature, or even fear and stress may affect these measurements. The next sections will explain each vital sign measurement in more detail by showing the effect of each one and its range.

Temperature: Temperature determination is an essential part of patient assessment. The measurement of temperature may be temporarily deferred in some emergency situation, but it must be noted that any severe fluctuation in body temperature constitutes a life-threatening emergency. The normal range of human body temperature varies due to an individual's metabolism rate; the higher (faster) it is the higher the normal body temperature, or the slower the metabolic rate the lower the normal body temperature. Other factors that might affect the body temperature of an individual may be the time of day or the part of the body in which the temperature is measured at. The body temperature is lower in the

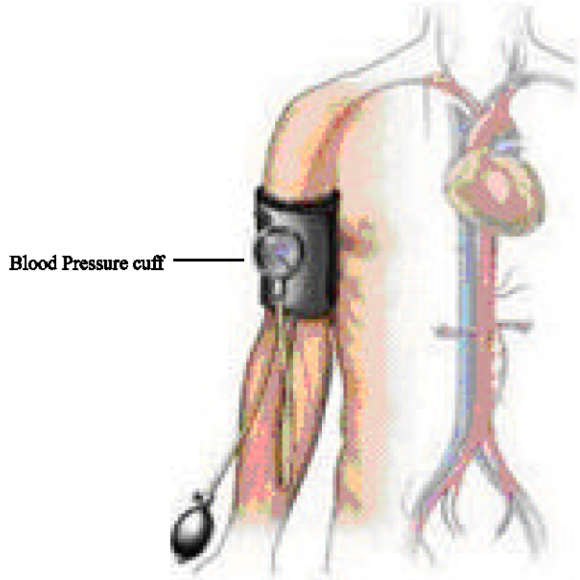

Fig. 2: Measurement of blood-pressure

morning due to the rest the body has received the night before and higher at night after a day of muscular activity and after food intake. In addition, the range can vary according to the age of the patient.

Blood pressure: Blood pressure is an essential parameter that is needed to determine the state of the patient. When the blood pressure is taken, as shown in Fig. 2, the doctor/nurse is measuring the pressure, or tension, that blood exerts on the walls of the blood vessels as it travels around the body. In a healthy person, this pressure is just enough for the blood to reach all the cells of the body, but not so much that it strains blood vessels' walls.

Blood pressure is measured in millimeters of mercury (mm Hg)[2,3]. A typical normal blood pressure is 120/80 mm Hg, or 120 over 80. The first number represents the pressure when the heart contracts, the second number represent the pressure when the heart relaxes. Blood pressure greater than 140/90 mm Hg is considered high. Generally, blood pressure will go up at certain times-for instance, if you smoke a cigarette, win the lottery, or witness a car crash-and will return to normal when the stressful or exciting event has passed. But when blood pressure is high all the time, the continuous increased force on blood vessels' walls can damage blood vessels and organs, including the heart, kidneys, eyes and brain.

Pulse rate : The pulse rate is the number of times a person's heart beats in one minute. Normal values for pulse rate depend on the person's age and fitness level. The measurements of the pulse rate are performed by putting slight pressure on any artery in which pulsations can be felt on the wrist. The pulse rate varies with different ages.

Respiration rate: Assessment of the vital sign respiration includes rate, depth and pattern of respirations. Respirations are best taken after the pulse, with the patient setting in a comfortable resting position. Count the respiration while still feeling the patient's radial pulse; this will decrease the possibility of the patient consciously trying to control the breathing. Respiration rate is normally affected by age, exercise, smoking, medication and emotional factors.

PROBLEM SOLUTION

Since the problem of categorizing patients depends on three factors (Vital Signs, Chief Complaints and Risk Factors), our solution consisted of three parts: the solution to the Vital Signs determination is mostly hardware-based because we simply replaced the old methods of measuring the vital signs by faster digital methods using sensors. For example, instead of measuring the respiration rate by looking at the patient's chest and counting his/her rate of movement, we measure it using an accurate differential gas pressure sensor. The solutions to the second and the third factors (Chief Complaints and Risk Factors determination) are purely software-based. This means our solution provides a complete diagnostic system which can imitate humans, not only in asking the right questions, but also in analyzing the answers using various artificial intelligence techniques.

Expert systems: The best approximation to the process of discovering the patient's priority level is the trouble-shooting process and the most widely used artificial intelligence system for trouble-shooting is the rule-based expert systems.

Rule-based expert systems have many advantages: They allow medical information to be presented in a simple way, as independent questions, that could be programmed and checked using a simple IF-THEN architecture.

We decided to enter the challenge of putting all the medical information in the form of questions, so the program could eliminate the use of the complicated and lengthy chief complaints diagrams. Instead the user will be asked a series of questions and will be allowed to choose between one of the two answers only, either yes or no, as shown in Fig. 3, so at the end after taking the measured vital signs into consideration, the program will give the patient's priority level.

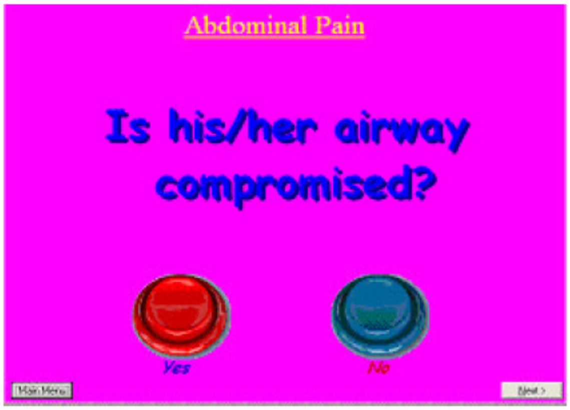

Fig. 3: A discriminator programmed for abdominal pain

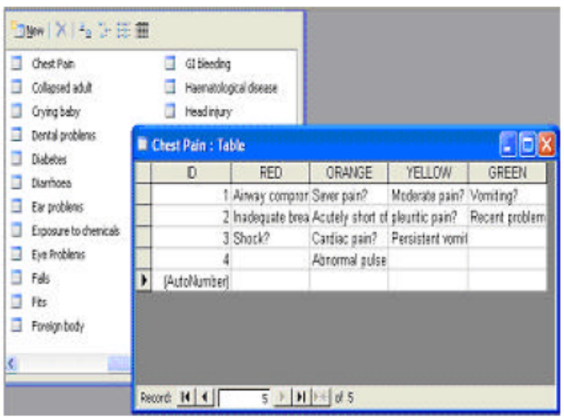

Fig. 4: A view of database linked to expert systems software

To achieve this we made the program think in conditional logic, so when the computer finds all the conditions which suggest a certain priority level to be true, it will directly give us the result without waiting for the yes or no answers for the remaining questions which are merely attesting the answers already given in the prior questions.

It is known that rule-based expert systems have one major disadvantage which is the inability to learn, so we were faced with the problem of having huge medical information to be entered into our program, In order to make our software self-learning, we connected our expert system to a database, containing each chief complaint in the form of a table, as shown in Fig. 4, with each priority level constituting a field and all discriminators leading to a column under this field.

In this configuration, not only it is very easy to enter the data now and the program can discriminate new cases and diseases, but future expansion is also possible. If any

Fig. 5: Starting screen of AEMS software

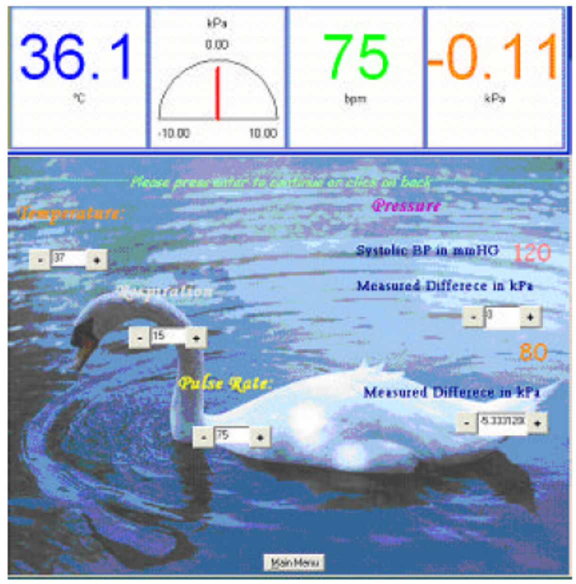

Fig. 6: Acquisition in AEMS software

new chief complaint is to be added to the database, all that is needed is to enter a new table in the database named the same as the title of the chief complaint and then insert the discriminators of each category.

Software design: The AEMS software basically consists of four main parts: Acquire, Diagnose, Patient files" and Telemedicine, as shown in Fig. 5. This software is aimed to be user-friendly, so that any computer-literate person whether familiar with the diagnosis in the emergency department or not can use it easily.

The acquisition part of the software which is shown in Fig. 6, gives the user a real-time display of the four vital signs, with the most common (normal) values of the vital signs available on the screen, so all what the doctor or the

Fig. 7: Diagnosis in AEMS software

nurse has to do is to accept the vital signs readings as they are or modify them (if desired) after the readings have stabilized.

The diagnose part of the software allows the user to choose the current chief complaint as shown in Fig. 7 to begin the process of asking questions (discriminators) about the chosen chief complaint of the patient.

When the artificial intelligence algorithm in the software becomes satisfied with the required questions asked, the program displays the result of the patient diagnostic by opening the window displaying the patient's priority level.

Hardware design: Data Acquisition is the process of taking the knowledge from one or more sources and passing on the acquired data in some suitable form to someone else or to another system. In this project, the patient is considered as the main source of the knowledge (questions and answers) and the knowledge of the vital signs' readings acquired from the patient through the connected hardware (sensors), is attached to the data logger (a substitute for external data acquisition card), which in turn is linked to the software which interprets the signals from the sensors. This type of acquired knowledge is classified as automated data acquisition and there are several advantages of using this method:

- Reduction in the high cost in human resources (special training) involved in obtaining the vital signs' readings.
- Better accuracy in acquiring certain kinds of measurements.
- Better speed in reaching decisions or conclusion about the status of the patient, compared to regular measurement methods.

The complete AEMS system is portable and can be moved to any desktop computer or laptop system installed in emergency department as well as anywhere else in the hospital or doctor's clinic.

Respiration rate sensor: The method used in our AEMS to measure the respiration is by wrapping a belt around the patient's chest. The respiration rate belt is a wide nylon belt and is fitted inside with an inflatable air bladder, which is connected to two rubber tubes. One of these tubes has a hand pump bulb that is used to inflate the air bladder. The other tube is attached to a Differential Gas Pressure Sensor to monitor the change in pressure as the patients chest expands and contracts during breathing. The differential gas pressure sensor has two ports to give an output relative to the difference of pressure between the two ports. The second port is left open to the atmosphere so that pressure will be measured relative to atmospheric pressure.

Blood pressure sensor: We decided to use another Differential Gas Pressure Sensor to measure blood pressure, but since it is not possible to compare the human blood pressure to atmospheric pressure (like what we did for respiration rate measurement), because the atmospheric pressure is very large, we came with the solution of fixing one port of the Gas Pressure sensor by connecting it to a cuff which has a 120 mm Hg pressure and connecting the second port to another cuff attached to the patient. This way, the systolic blood pressure of the patient can be measured by taking the difference between the patient's blood pressure and the fixed one, when a zero pulse rate is displayed on the software screen which indicates that there is no flow of blood in the artery. The disystolic blood pressure can be measured after releasing the air in the cuff until we get the same pulse rate which was recorded before measuring the blood pressure, which means at the moment when the flow of the blood in the artery is returned to normal again.

Pulse rate sensor: The pulse rate sensor used in our AEMS monitors the light level transmitted through the vascular tissue of the fingertip or the ear lobe and the corresponding variations in light intensities that occurs as the blood volume changes in the tissue. The infrared light emitted by the LED is diffusely scattered through the fingertip or ear lobe tissue. A light sensitive detector positioned on the surface of the skin on the opposite side can measure light transmitted through at a range of depths. Infrared light is absorbed well in blood and weakly absorbed in tissue. Any changes in blood volume will be registered since increasing (or decreasing) volume will cause more or less absorption. Assuming the patient does not move, the level of absorption of the tissue and non-pulsating fluids will remain the same.

Temperature sensor: The temperature sensor has thermostat wires connected to its end. These wires are covered by highly flexible heat-shrink tubing. This makes the sensor suitable for measuring temperatures when it is attached to the body. The best reading from this sensor is obtained when the thermostat wires are placed under the tongue, so we used a special disposable plastic coating to cover the thermostat wires in order to be safe when it is used again by other patients.

CONCLUSION

The development of this system proves that there are many areas in which artificial intelligence (or computer engineering in general) could be applied to solve complicated everyday life problems and the functionality of the system can be more extended simply by adding or modifying some components. For example there is a limited telemedicine functionally in the current AEMS system, which can be further developed by implementing networking functionality, enabling a large company to get a preliminary diagnosis for one of its employees who is working in a remote area, without having the employee checked by a doctor in his area, but with having him connecting himself to the sensors and the reading feeding to the doctor in the head office across the computer network. Using a digital camera to chat with the patient and to answer the expert systems questions asked by the AEMS, the doctor can do the preliminary diagnosis of the patient who is at a remote distance and dispatch appropriate medical care to the location.

The AEMS was designed to compensate for doctor's experience to a great extent, but it does not substitute it. Furthermore, the program keeps track record of all patients in a database. This helps future referencing, investigations and surveys.

Our system not only avoids measuring vital signs using old methods, but also allows monitoring physical parameters such as temperature, blood pressure, respiration rate and pulse rate in real-time. The problem faced by us in measuring the blood pressure using commercialized differential pressure sensors could be overcome by designing a fit-to-purpose intelligent technique. Future work could focus on the following three main axes:

- Strive to procure sensors meant for biological purposes and integrate sensors and data logger in single hardware-board, i.e., an Application Specific Integrated System (ASIS). This will reduce noise effects, increase system reliability and make the system extremely portable.
- Develop an advanced telemedicine feature through Internet or phone lines that will help patient's diagnosis when the patient is at a remote distance.
- Replace the doctor or nurse's task of posing questions and entering answers by a speech recognition system. This will be like the ATM-banking system with speech-recognition facilities and will allow quick categorization of the patient's priority level in the emergency department.

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