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## **SIMULATION OF MEDICAL DATA AS A WAY OF SPEEDING UP DEVELOPMENT OF ALGORITHMS FOR A SYSTEM FOR ESTIMATION OF PATIENT'S HEALTH**

**Summary.** This paper presents decision support system for estimation of patient's general state, with particular stress laid on cardiovascular and pulmonary diseases. It works in conjunction with a standard medical monitor, which provides asset of input signals (for development stage signals are also simulated). The signals are preprocessed and analysed by a set of algorithms, the core of which is based on Bayesian networks. As an output the system should give information about detected problems, eventual future threats, possible causes and suggestions for further treatment.

**Keywords:** cardiovascular diseases, hospital treatment, decision support system, artificial intelligence, MEWS.

## **SYMULACJA DANYCH MEDYCZNYCH JAKO SPOSÓB PRZYSPIESZENIA ROZWOJU ALGORYTMÓW SYSTEMU OCENY STANU PACJENTA**

**Streszczenie.** W artykule przedstawiono system wspomagania decyzji odnośnie do oceny stanu ogólnego pacjenta, ze szczególnym naciskiem położonym na choroby układu krążenia i układu oddechowego. Działanie tego systemu jest oparte na danych wejściowych ze standardowego monitora funkcji życiowych (w fazie rozwoju algorytmów dane są również symulowane). Sygnały są przetwarzane i analizowane za pomocą algorytmów opartych, przede wszystkim, na sieciach Bayesa. System na wyjściu powinien generować informację na temat wykrytych problemów, przyszłych zagrożeń, przyczyn pogorszenia zdrowia i propozycji dalszego leczenia.

**Słowa kluczowe:** choroby układu krążenia, hospitalizacja, system wspomagania decyzji, sztuczna inteligencja, MEWS.

## 1. Introduction

The most common causes of deaths in the world are cardiovascular diseases [5]. This phenomena is true also for Polish patients. These diseases are characterised by often sudden onsets of the severe stage of illness, leading to a rapid deterioration of patient's state. Sudden Cardiac Arrest (SCA) could be considered as the most dangerous as it is the most common cause of hospital mortality. If such a deterioration takes place, immediate actions have to be taken in order to save patient's life. The best approach would be to predict the onset of the severe stage in order to take preventive steps before the actual deterioration takes place.

The experiences with the Modified Early Warning Score (see Section 2) show that even such a simple approach allowed to reduce the risk of SCA and hospital mortality [2]. It is therefore tempting to expand this approach to make it automatic, based on more data and utilising advanced reasoning algorithms. This paper presents research aimed at developing such a system.

## 2. Diagnosis Support Systems

Modified Early Warning Score (MEWS) is a simple scale used in hospitals and by paramedic services to quickly determine the patient's condition and changes of this condition. The simplicity of the scale allows the score to be computed without the need of any computing device, simply by referring to a compact chart summarising the possible values of vital parameters, as presented in Table 1. The rise of the score by a value of 2 is treated as an indication for consultation with a doctor, while the rise by a value of 4 – as an indication for immediate transfer to the Intensive Care Unit.

Even though MEWS has proven effectiveness, it is a very simple scale. It does not make use of data currently often available, even in the simplest paramedic scenarios such as, for example, the Electrocardiography (ECG) signal. Moreover, the concept of combining the input data using a table is possible only in very simple cases of few inputs.

It should be stressed, that there are in use much more elaborate scales (for example, the Acute Physiology, Age, and Chronic Health Evaluation - APACHE III). They allow to include much more input data, but this makes the use of such a scale difficult in the paramedic or Emergency Department environment: all parameters have to be entered into a computer program manually.

Table 1

A sample MEWS chart

Readings, observations	Score						
	3	2	1	0	1	2	3
Systolic blood pressure	<45%	30%	15% down	normal for patient	15% up	30%	>45%
Heart rate [beats/min]	-	<40	41-50	51-100	101-110	111-129	>130
Respiratory rate [breaths/min]	-	<9	-	9-14	15-20	21-29	>30
Temperature [°C]	-	<35	-	35.0-38.4	-	>38.5	-
AVPU	-	-	-	A	V	P	U

Source: Subbe C.P., Kruger M., Gemmel L.: Validation of a modified Early Warning Score in medical admissions. *Quarterly Journal of Medicine* 94, 2001, p. 521-526.

In recent years, a number of computerised decision support systems for use in diagnosis of cardiovascular diseases have been designed, including systems based on advanced concepts of soft computing. For example, in [4] the authors propose a system for diagnosis of chest pain utilising rule-based inference. The system is based on the knowledge learned from real patient data. In [3], the authors propose another system for chest pain diagnosis using ontology approach and Bayesian networks. Yet another method is outlined in [7], where data mining algorithms and fuzzy models are used as a basis for the decision support system.

Although such computerised systems proved their usefulness in improving quality of care [8], [1], [6], it should be stressed that none of them automatically acquires the data about the patient in real-time. They are simply based on offline patient records or additional questionnaires. They also cannot respond to the quickly changing patient's state. The system proposed in this paper aims to overcome these difficulties.

### 3. New strategy for patients' monitoring

Nowadays doctors use various types of medical monitors for monitoring their patients. These could be quite simple devices with only few parameters available, but also very complex ones. More complex monitors can perform also invasive measurements, even using Swan-Ganz catheter. Medical monitors present current values of parameters and store historical data available for doctors later on. Doctors taking care of a patient can use data for assessing patient's state. Such approach is good enough when the patient is already diagnosed and possible threats and problems are determined. However, in places

such as Accident Emergency Departments and Admission Rooms usage of medical monitors is less common. Small medical staff has to cope with a number of patients that may quickly develop various medical problems. Therefore doctors do not have time for detailed observations of variety of vital parameters and in particular their changes in time.

This is the place for creating a whole new strategy for short-time patients monitoring that supports pre-diagnosis. Patient arriving, for example, to Admission Room could be connected to a monitor with additional device performing assessment of his health. This device at the same time, using artificial intelligence techniques, can search for possible causes of problems and suggest further treatment. Such a short monitoring could not determine exact problems, but would be able to show most probable areas of cardiovascular issues. When doctor have this information, he can make diagnosis much quicker, which is extremely important in most cases.

What is more, symptoms for many health problems – especially cardiovascular and pulmonary complications – may be hidden in various combinations of many different vital parameters and their dynamics. This is why adding support for automatic assessment of patients' state seems to be reasonable way for developing a new strategy for monitoring patients in hospitals.

#### **4. Proposed system overview**

Medical monitors, widely used in today's hospital and paramedic practice, acquire constantly a number of signals that are indicators of a patients' health. The most typical signals include: ECG, body temperature, respiration rate, blood oxygen saturation and blood pressure. Virtually all monitors support exporting the acquired data: either by saving them on removable flash memory, or by continuous transmission using popular network standards (typically IEEE 802.3/Ethernet).

The proposed solution relies on the medical monitor as a data source. Such an approach has a number of advantages:

- reduced cost, as it utilises the infrastructure already present in the hospitals/ambulances,
- simpler operation, as there is no need to attach additional wires to the patient,
- easier development, as it is not required to develop the part responsible for acquiring signals.

For implementation, it is necessary to work with medical monitor that exports data in a continuous manner, and to understand the format of data employed by the monitor. For development purposes, an Emtel FX2000-MD (Figure 1) has been selected – it exports data over an Ethernet connection and the manufacturer made the data format available for the purpose of research.



Fig. 1. Emtel FX2000-MD medical monitor used in the project

Rys. 1. Wykorzystany w projekcie monitor funkcji życiowych Emtel FX2000-MD

The key to obtaining the desired functionality is the software running on an embedded processor. The software consists of a number of interconnected blocks. These can roughly be divided into: input/preprocessing blocks, AI blocks and output/presentation blocks. The task of the first is to gather data from the monitor, according to a specified data format, and perform preprocessing of these data. This preprocessing varies from very simple (averages, differences over time) to advanced (detecting predefined anomalies in the ECG data). The task of the AI blocks is to combine all input data in order to reach a conclusion about patient's state and detect indications of state deterioration. Bayesian network has been chosen as the main AI approach in the proposed solution. It is planned that AI modules based on other approaches will also be constructed, in order to allow comparison of performance; however, for the time being, efforts are focused on the Bayesian network.

Bayesian networks employ directed acyclic graphs to encode qualitative relationships between variables. The nodes of the graph correspond to the variables, and the edges correspond to the dependences between them. Inference with Bayesian networks involves setting the state of the observed variables (entering evidence) and applying one of numerous algorithms that allow to compute probabilities of the other variables. It is possible to freely choose the nodes for which the evidence is entered, so the Bayesian network is an ideal tool for reasoning in cases, when some of the input data might be missing.

The output/presentation blocks are responsible for presenting the results of analyses to the medical staff and also storing these for further references.

## 5. Patient data

Developing Bayesian networks that cover many dangerous cardiovascular diseases and other health problems requires two different types of information. The first type is medical knowledge that can be gathered from doctors and medical literature and is quite easily available. The second type are data (gathered from medical monitor) from patients of various general states, suffering from different diseases. Process of gathering such data is difficult and highly time-consuming, as it should be gathered from many patients. It has to be stressed, that currently the developed system can cooperate with one medical monitor. All data for the development stage of the project should be taken from this monitor. To get data from patients, three conditions should be fulfilled at the same time:

- the cardiovascular condition of the patient should be known exactly,
- this patient should not be monitored in other way (as there can be conflicts in sensors, especially electrodes – placement),
- there should be no medical contraindications for monitoring the patient.

Fulfilling all these conditions together is difficult and makes gathering data extremely time-consuming. Therefore, it seems reasonable to develop a new strategy for obtaining input signals. Data that are not available from hospital measurements, but are needed, should be added to the set by performing a simulation. The proposed approach is to begin with data from healthy individuals, which are more readily available, and modify them in order to produce symptoms characteristic of a particular disease. For different diseases, individual signal-modifying algorithms would be implemented. Some of them involve only numerical parameters changes, but most of them have to modify also more complex signals, such as ECG or ICG.

Various patients' conditions can cause different changes in vital signals. To simulate such situations the algorithms have to modify many parameters of the signal. For example, ECG modification can be performed by taking such actions as: ST segment level change, T-wave inversion/flattening, extension of the QRS complex, P-wave amplitude change or prolongation of the PR interval. Of course, mentioned changes have to be synchronised with modifications applied to accompanying data (body temperature, blood pressure, etc.), according to the medical knowledge about the particular disease.

The proposed approach has an obvious advantage in allowing to speed up the development process significantly. Implementation of algorithms and gathering data are both the most time-consuming stages of the whole project. The proposed method makes both steps independent from each other. Of course, this approach has also disadvantages: simulations will likely exhibit some deviations from the real data. Algorithms developed on the basis of simulated data will have to be very carefully examined after real data

are available and probably corrected afterwards. Taking into account time gain that comes from proposed strategy, it seems to be the best approach for the project discussed in this paper.

Java programming language was chosen for implementation of this solution. As different diseases needs various algorithms, they could be easily organized as Java plugins for the application and treated separately. What is more, the simulation software will be movable between various systems, as Java applications are platform-independent, and there are plenty of solutions for charting signals in Java, that facilitate the implementation.

## 6. Conclusions

This paper presented work concerning development of a real-time multiparameter system for assessing patients' general condition, with particular stress laid on cardiovascular diseases, with standard medical monitor as a data source. The aim of the system is to provide support for (para) medical staff, especially in situations where the doctors may not be immediately available or have to attend a large number of patients. Use of the presented system might be especially important in places such as Accident Emergency Departments and Admission Rooms, where small medical team has to take care of many patients in various general conditions.

At this moment, work focuses on the development of the Bayesian network, the central reasoning element of the system. The initial structure of the network is designed and the numerical specification is being constructed. Once this step is completed, the system will be subjected to clinical tests. Conducting research connected with Bayesian network is available thanks to the concept of simulated data presented in this paper.

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## Omówienie

Choroby układu krążenia są jedną z najczęstszych przyczyn zgonów na świecie. Pomimo rozwoju technik resuscytacji, nagłe zatrzymanie krążenia (NZK) wciąż obarczone jest złą prognozą. W celu zmniejszenia ryzyka wystąpienia NZK, zaproponowano nowe podejście do monitorowania pacjentów, polegające na wczesnym wykrywaniu zagrożeń. Przydatność takiego podejścia jest szczególnie istotna w miejscach takich jak Szpitalne Oddziały Ratunkowe oraz Izby Przyjęć. System oceny stanu pacjenta współpracuje ze standardowym



monitorem funkcji życiowych, będącym źródłem danych wejściowych, takich jak: temperatura, wysycenie krwi tlenem czy sygnały EKG i ICG. Ocena dokonywana jest na podstawie sieci bayesowskich. Istotnym etapem w rozwoju systemu jest przygotowanie danych symulacyjnych, pozwalających na szybsze opracowanie algorytmów.