Computer Standards & Interfaces 44 (2016) 42–53

Contents lists available at ScienceDirect

Computer Standards & Interfaces

journal homepage: www.elsevier.com/locate/csi

A novel blood pressure verification system for home care

Victor R.L. Shen [a,b,*], Yu-Ying Wang [c], Li-Ya Yu [d]

[a] Department of Computer Science and Information Engineering, College of Electrical Engineering and Computer Science, National Taipei University, 151, University Rd., Sanhsia, New Taipei City 237, Taiwan
[b] Department of Electronic Engineering, Ming Chi University of Technology, 84, Gungjuang Rd.,Taishan District, New Taipei City 24301, Taiwan
[c] Department of Applied Japanese, Jinwen University of Science and Technology, 99, Anzhong Rd., Xindian Dist., New Taipei City 23154, Taiwan
[d] Graduate Institute of Electrical Engineering, College of Electrical Engineering and Computer Science, National Taipei University, 151, University Rd., Sanhsia, New Taipei City 237, Taiwan

ARTICLE INFO

Article history:
Received 5 January 2014
Received in revised form 12 July 2015
Accepted 14 September 2015
Available online 25 September 2015

Keywords:
Fuzzy analytic hierarchical process (FAHP)
Blood pressure control
Real-time home care
Petri nets

ABSTRACT

Since the human resource-intensive traditional medical care practices often lack consideration of natural human reasoning, they follow procedural knowledge as the knowledge base, and therefore, they lack precision of knowledge description. In order to reduce dependency upon human resources and quickly and accurately discern a patient's health condition, we have constructed a fuzzy blood pressure verification system, which consists of an intelligent mobile device integrated with fuzzy comparison and a fuzzy analytic hierarchical process. This personalized and humane blood pressure verification system can provide assistance for the health and safety of the elderly. In stage one, the system development involves computation of the hierarchical levels of patient's various physiological data using the fuzzy analytic hierarchical process (FAHP). In stage two, a fuzzy blood pressure verification system was constructed using the fuzzy analytic hierarchical process and high-level fuzzy Petri nets. Plotting functionality was added for the convenience of observing the blood pressure trends in patient records in the database system. Upon detection of an abnormal physiological signal from a patient, the intelligent mobile system can generate an alarm, thereby facilitating real-time home care.

1. Introduction

As information technology advances rapidly and the quality of life needs to be improved, the humanist and intelligent living spaces are becoming a reality. People who require care, such as the elderly and those people suffering from chronic illness, require daily monitoring of blood pressure, heart rate, and body temperature. Given the trend of aging populations combined with declining birth rates observed in recent decades, the current working forces are faced with an ever-growing burden of providing care for the elderly [3,4,10,20]. Humanist and intelligent home care technology has been replacing the traditional hands-on aged care by combining the aged care with monitoring and information technology. This enables home care to be flexible, intelligent [9], and compassionate, in the hope that individual health awareness can be raised, medical expenditure can be lowered, and the quality of health care can be increased [1,2,3].

A fuzzy verification system allows users to verify a rule class that is a collection of knowledge about a specific problem. When the estimation of a specific problem is performed, the specific rule class can be appointed as the knowledge base, with environment or any other factors relevant to the problem as additional rules. Fuzzy estimation works well based on the degree of certainty [2,20]. In such an estimation model, the certainty of a rule represents a change in the possibility of the fact post estimation [7]. The possibility of a fact is recalculated based on its original possibility and the degree of certainty in a rule. We have used this approach for designing the blood pressure verification system.

The current research report shows that half of the top ten causes of death in Taiwan are related to hypertension, making it a serious health risk [7,12,13,19]. On this basis, the main purposes of this paper include the following:

1. using results of the fuzzy analytic hierarchical process as a basis for tele-home care, generating alarms, and notifying the patient's family when the patient's blood pressure becomes abnormal;
2. adding functionality of plotting to the database to allow comprehensive monitoring of the patient's physiological changes;
3. combining the experimental results with intelligent devices, creating a knowledge system that closely resembles human thinking, thereby realizing humanistic health care.

The remained sections of this paper are organized as follows: Section 2 discusses the definition of a home care system, blood pressure and cardiovascular conditions, and a high-level fuzzy Petri net (HLFPN).

* Corresponding author at: Department of Computer Science and Information Engineering, College of Electrical Engineering and Computer Science, National Taipei University, New Taipei City 237, Taiwan.
E-mail addresses: rlshen@mail.ntpu.edu.tw, victor.rlshen@msa.hinet.net (V.R.L. Shen), wyy12@just.edu.tw (Y.-Y. Wang), a224953154ya@yahoo.com.tw (L.-Y. Yu).

http://dx.doi.org/10.1016/j.csi.2015.09.008
0920-5489/

Section 3 describes the methods of creating a fuzzy blood pressure analysis system using the fuzzy analytic hierarchical process (FAHP) combined with the HLFPN. The system transmits pulse and blood pressure data gathered by the blood pressure monitoring and management system. In Section 4, the structure and operating steps of the implementation in experiments are explained, followed by a discussion of experimental results from diastolic pressure measurements, and comparisons after connecting with an intelligent device. In Section 5, the results from all of the preceding sections are summarized and a conclusion is given. Suggestions for the follow-up research are also proposed.

2. Literature review

In this section, first of all, the definition and measurement methods of blood pressure are presented. Finally, the knowledge verification and the definition of high-level fuzzy Petri nets are discussed [6,10].

2.1. Measurement of blood pressure

The blood pressure measuring devices can be divided into two major categories, namely, *invasive* and *non-invasive*. During a routine medical examination, the blood pressure is usually measured using either the auscultatory method or the oscillometric method, both of which are non-invasive. This measuring method is normally carried out in hospitals; however, now that basic cardiovascular status assessment can be performed at home, personal health can be better guaranteed. The device developed in this study adopts the architecture of an electronic blood pressure machine, manipulates values captured by the built-in pressure sensor, and then transfers them to a desktop computer, using Bluetooth, RS 232, or 3G protocols and standards, to be plotted. Those data items that cannot be captured from a standard home device such as blood oxygen and blood oxygen levels can be captured by our device. Using our device, the patient is able to perform basic cardiovascular status assessment at home with ease, promoting early detection and helping the family control cardiovascular disease.

The report by the Joint National Committee regarding the prevention, evaluation, and treatment of high blood pressure [14] has determined that the optimal range for blood pressure for an adult over the age of 18 is below 120 mmHg for systolic pressure and below 80 mmHg for diastolic pressure, while the measurements below 130 and 85 mmHg, respectively, are considered to be *normal*. Systolic pressure between 130 and 139 mmHg and diastolic pressure between 85 and 89 mmHg are considered to be *high-normal*. Collectively, the systolic pressures below 140 mmHg and diastolic pressure below 90 mmHg are considered to be within a normal range, as shown in Table 1 [6,15]. The traditional binary logic only allows these values to be interpreted as yes/no or true/false scenarios, determining if a patient's hypertension is severe enough to require medical care, to take medication, or is within the normal range.

In the fuzzy expert system, the conditions and conclusion of a fuzzy rule may incorporate descriptive semantics like those used in natural language, such as "more," "quite," "very," "slightly," and "extremely." Use of such semantics allows much more appropriate fuzzy descriptions to be achieved, such as "very big," "big," "slightly big," "medium," "slightly small," "small," "very small," "ideal blood pressure," "normal pressure," "high-normal pressure," "mild hypertension," "moderate hypertension," and "severe hypertension" [11,12,23].

Table 1
Classification of blood pressure.

Classification	Systolic pressure (mmHg)	Diastolic pressure (mmHg)
Optimal	<120	<80
Normal	120 ~ 140	80 ~ 90
Mild hypertension	140 ~ 159	90 ~ 99
Moderate hypertension	160 ~ 179	100 ~ 109
Severe hypertension	≧180	≧110

Table 2
Sorting time comparison between HLPN model and HLFPN model.

	HLPN model	HLFPN model
1	1.3654	0.9663
2	1.3592	0.9481
3	1.4661	0.9333
4	1.4732	0.9521
5	1.5657	0.93
6	1.644	0.922
7	1.5094	0.937
8	1.5465	0.9385
9	1.4885	0.9771
10	1.3697	0.9379
11	1.6572	0.9987
12	1.647	0.9582

2.2. High-level fuzzy Petri nets

Like the neural network, the fuzzy Petri net (FPN) model can be used to describe the representation of knowledge structure using Petri nets, and the mechanism of inference using fuzzy theory [5,9,11,16,21]. In recent years, the study of knowledge verification using Petri nets among rule-based expert systems has gained increasing attention. Petri nets are a graphical and mathematical tool applied in many areas of research for information processing. The advantages of a rule-based Petri net system are that it provides an ideal platform for analysis and graphical presentation, representing rules in a structural way, deducing the process of inference, and then allowing the dependency relationships between rules to be clearly understood [4]. As a result, many academics have proposed their own customized Petri net models to describe the rule-based system. At the same time, many studies on the applications of fuzzy reasoning have been published [8]. The traditional Petri nets have been extended to become an FPN model and a high-Level petri net (HLPN) model [21]. The HLPN provides a solid definition for the model design, analysis, and verification of parallel systems, which fuzzy Petri nets lack. Therefore, the consolidation of the two models, allowing reuse, reliability, expandability, and variability of existing data, acts as a complete mechanism for system design, analysis, and verification [22].

Twelve sample data sets to compare the time of sorting blood pressure by HLPN model with that by HLFPN (high-level fuzzy Petri nets) model under the same condition are adopted. In Table 2, assuming the blood pressure is 115, the average sorting time used by HLFPN is 0.949 second and the sorting time used by HLPN is 1.507 second, we can clearly see that the HLFPN model performs much better than the HLPN model.

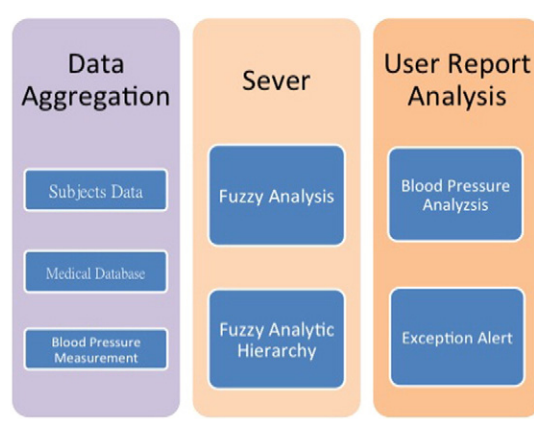

Fig. 1. Fuzzy blood pressure verification system.