Contemporary Engineering Sciences, Vol. 10, 2017, no. 32, 1595 - 1603
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/ces.2017.710147

Line Design of a Monitoring and Emergency Network to Help in the Study and Prevention of the Sudden Infant Death Syndrome

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Abstract

Sudden infant death syndrome (SIDS), also known as cot death or crib death, is the first cause of death in children between the ages of 2 and 12 months. In this paper, we outline the creation of a monitoring and emergency net which applies the internet of things (IoT) to get real-time information regarding the cause of SIDS and turn the system into a prevention and early diagnosis tool. An algorithm coded in MATLAB R2013a (Mathworks) will be implemented to assess the patient's vitality, using fuzzy logic, and recollect information about the different phases of the disease.

Keywords: Biomedical Computation, Fuzzy Logic, Infant Vital Signs, Internet of

Things, Real-Time Alarms, Sudden Death, Vitality Classification and Wearable Device

1 Introduction

Considering the evolution of technology including wireless body area network (WBAN) and the Internet of Things (IoT), better opportunities are possible for monitoring a patient’s vitality in real-time and for a long term [1]. Small devices can be placed in the patient’s body, clothing or accessories to silently monitor his vitality without any risk from the comfort of his home or in the development of everyday activities, detecting irregularities and alerting the parents or the medical staff of an emergency [1] [2]. In this work, a remote real-time monitoring system is proposed using an intelligent system with fuzzy logic [1]. The idea is to simulate the transmission of signals such as cardiac rhythm, respiratory frequency, body temperature (through the skin), blood pressure and oxygen saturation; this generates different cases of patient vitality (normal and abnormal). Additionally, the information is stored to establish a statistical analysis with all the gathered data and thereby increase the information on the syndrome. The statistical analysis of data can help find new and relevant information regarding the sudden death syndrome. However, this work focuses on doing a better constant monitoring of the patient at risk so that it has a positive and opportune impact in the early detection of the disease so that parents and doctors can intervene and avoid subsequent injuries or even death.

2 Background

The sudden infant death syndrome is the number one cause of death in patients between the ages of 2 and 12 months [3]. To be defined as sudden death, the cause of death must remain unexplained after an exhaustive research that includes the revision of the medical record, examination of the place of death and complete autopsy.

The development of new technologies has allowed the creation of systems that can constantly monitor (even at long distances) the patients in hospitals or at home. In [2] a monitoring system was developed and tested using a Raspberry Pi. Similarly in [4] a non-invasive biosensor is shown to monitor the respiratory rhythm in real-time. In [5] a system that monitors the vital signs of the patient is detailed. It also facilitates the treatment of diseases using Telemedicine. In [6] and [7] a pajama was designed to monitor babies while they are asleep. Currently, there are many systems capable of monitoring a patient in real-time. The challenge lies in what to do with the collected information. In [8] an adequate treatment of the signal is shown so that it can be correctly interpreted through the elimination of noise and the interference of the vitality signals. [9] shows how easy it is to apply fuzzy logic in the study of a patient’s vitality, and in [1] a fuzzy logic algorithm is designed for a real-time monitoring system.

3 Methodology

MATLAB R2013a (MathWorks) and the Fuzz Logic Toolbox were used to implement the fuzzy logic interface. Five input values were used which correspond to the most important vital signs as defined in The Royal Children's Hospital Melbourne [10] : Respiratory frequency (fR), Cardiac rhythm (RC), Arterial pressure (PA), Cutaneous body temperature (T) and Oxygen Saturation (SO2). These variables are used to assess the condition of every patient. For each variable there is a corresponding range and a fuzzy modifier, which will be showed in the following section.

Table I. Range of Values Heart Rate in Men In Rest

Heart pulse in males in resting state				
Age (years)	**Inadequate (bpm)**	**Normal (bpm)**	**Good (bpm)**	**Excellent (bpm)**
20 - 29	86 or more	70 - 84	62 - 68	60 or less
30 - 39	86 or more	72 - 84	64 - 70	62 or less
40 - 49	90 or more	74 - 88	66 - 72	64 or less
50 or more	90 or more	76 - 88	68 - 74	66 or less

4 Implementation

Table II gathers the ranges of the physiological values used in this article. The values that are too high or low are considered as critical state; the low and high values are considered states of alert and the normal values are the normal state. For the variables of respiratory frequency, cardiac rhythm and body temperature, there are five possible ranges: two for critical state, two for a state of alert and one for the normal state. For arterial pressure there are only three ranges: two for the state of alert and one for the normal state. Finally, the oxygen saturation has three ranges: one for each state (critical, alert and normal). Table I also shows the levels assigned to each range in the defuzzification process. Figures 1 to 5 show each variable's defuzzification.

TABLE II. Ranges Corresponding to the Vitality Variables

Variable	**Very low**	**Low**	**Normal**	**High**	**Very High**
fR [Respirations per minute]	<15	15-30	30-60	60-80	>80
RC [Heartbeats per minute]	<95	95-105	110-165	165-180	>180

TABLE II. (Continued): Ranges Corresponding to the Vitality Variables

PA [mm Hg]	-	<65	65-115	>115	-
T [o C]	<35.5	35.5-36.5	36.5-37.5	37.5-38.5	>38.5
SO2 [%]	<90	90-95	95-100	-	-

Figure 6 shows an example of the fuzzy logic rules applied to the proposed work. It can be seen how the vitality of the patient is normal. Due to the number of variables that are considered to measure the patient's vitality there was an estimate of 1125 rules of logic.

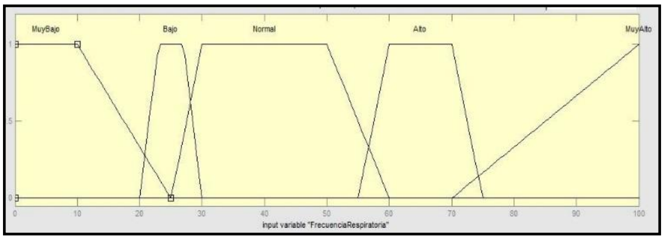

Fig. 1. Defuzzification function for respiratory frequency. Source: Authors.

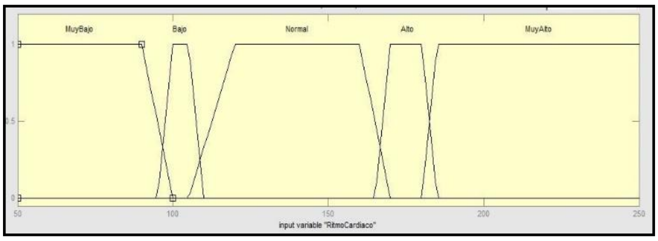

Fig. 2. Defuzzification function for cardiac rhythm. Source: Authors.

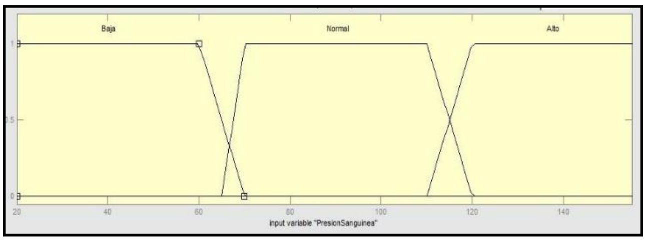

Fig. 3. Defuzzification function for arterial pressure. Source: Authors.

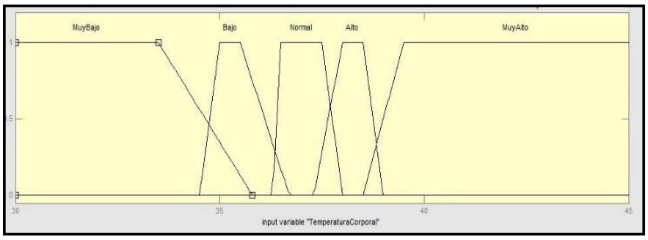

Fig. 4. Defuzzification function for body temperature. Source: Authors.

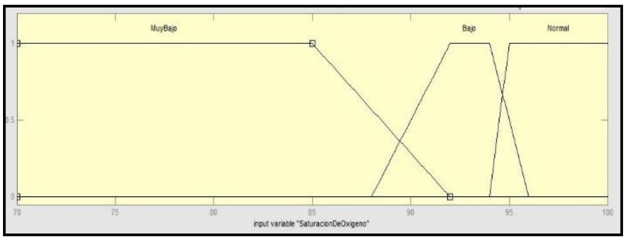

Fig 5. Defuzzification function for oxygen saturation. Source: Authors.

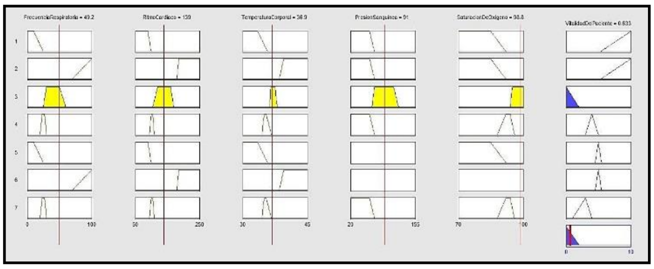

Fig. 6. Basic rule example for a normal vitality case. Source: Authors.

Fuzzy logic is used to encompass all possible cases. To simplify and adapt the algorithm specifically for the SIDS, different weight functions were assigned to the variables giving priority to the respiratory frequency and cardiac rhythm which change during sleep. Hence, it was only necessary to create 150 rules. Figure 7 exhibits a representation of the relationship described for the rules of the algorithm between the respiratory frequency and the cardiac rhythm. The idea is to work with the medical staff to make the algorithm capable of defining a patient's vitality as a doctor would do in charge of the case.

5 Results

To examine every patient, the values of five vitality variables are necessary. Once the variables are inputted (Figure 8), the algorithm assigns a number between 0 and 10 (Figure 9). The patient's vitality can be catalogued in five possible ranges (Table II). The range from 0 to 2 represents a normal state and does not require any additional action. The range from 2 to 3 represents an altered state. This state does not require any additional action because the baby can be asleep. However, it is not considered under the normal state since the baby's sleep period is the most important moment of monitoring for the SIDS. The range from 3 to 4.5 is a highly altered state and the patient's parents need to be informed. For the range from 4.5 to 5.5 there is a state of urgency, the parents are informed and the health care professional in charge is contacted. Finally, in the range from 5.5 to 10, there is a state of emergency where the parents and health care professionals are contacted and an emergency service is called to assist the patient in the least amount of time possible.

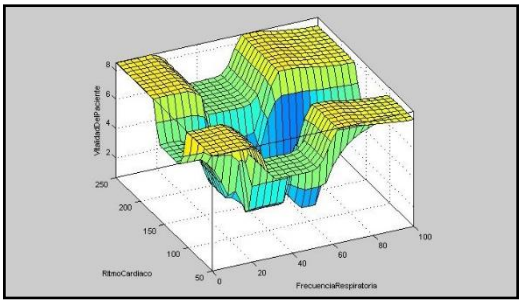

Figure 7. Relationship between the respiratory frequency, the cardiac rhythm and the patient's vitality. Source: Authors.

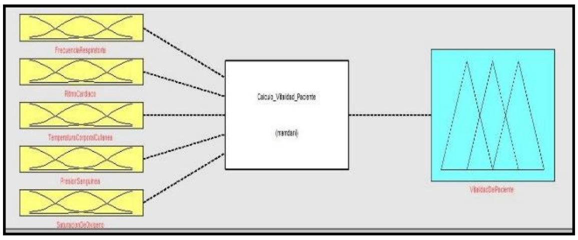

Figure 8. Fuzzy logic algorithm work flow. Source: Authors.

The decision module (Table II and Figure 9) delivers a module for the patient's vitality and, depending on that value the necessary measures are taken whether the parents or the medical staff in charge is contacted or ordering an emergency service.

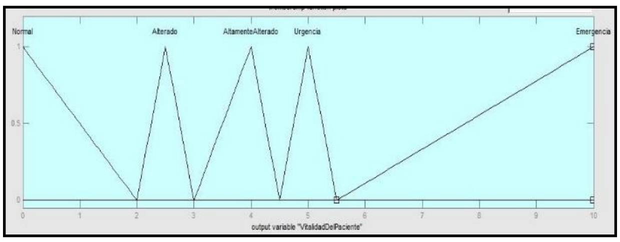

Figure 9. Fuzzy assignation output of the patient's vitality. Source: Authors.

TABLE III. Classification of the patient's vitality

Range	Assignation
0 - 2	Normal
2 - 3	Altered
3 - 4.5	Highly altered
4.5 - 5.5	Urgency

6 Results Discussion

Due to the lack of information concerning the vitality of babies between the ages of 2 and 12 months, the effectiveness of the algorithm was tested using a test system where the medical staff would evaluate the patient's vitality and thereby measure the effectiveness of the algorithm. A sample of 72 cases of normal and abnormal vitality was created to have a confidence level of 95% and a maximum error of 5%. The frequency in which the diagnosis coincide was analyzed and it was determined that 94% of the cases (68 of them) coincided and only 6% did not (the remaining 4 cases). Table III shows seven examples of samples created to evaluate the efficiency of the algorithm presented in this article.

7 Conclusions

The main objective of this project has been the design of monitoring and emergency system to collaborate in the study and prevention of the SIDS. Therefore, a fuzzy logic algorithm was implemented to assess a patient's vitality using respiratory frequency, cardiac rhythm, body temperature, arterial pressure and oxygen saturation. For the algorithm, 150 rules were created to determine the state of the patient. These rules do not all come from the combination of physiological variables but were established through weight functions to give more importance to some variables (respiratory frequency and cardiac rhythm) in order to render the algorithm more accurate and focused on the sudden infant death syndrome.

8 Future Work

As future work, it is proposed to build a module that connects any system that measures the vitality variables used in this work and delivers the patient's vitality in real-time. It is also proposed to design response protocols for each vitality state delivered by the algorithm, whether it implies varying the sampling time of the vitality variables or the type of alarm (visual or sonorous) or the hired medical staff. Finally, it is proposed to create a storing and statistical analysis module of the data used to assess the vitality of 2 to 12 months old patients. This has the purpose of increasing the information available concerning the sudden infant death syndrome.

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Received: November 1, 2017; Published: December 20, 2017