Body Monitoring System Using Rule Based Sensor Networks

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Abstract:**Wireless Body Area Network (WBAN) in recent years has received significant attention, due to their potentiality in various applications. The WBAN system can monitor physiology signals (such as body temperature, electrocardiogram (ECG), blood pressure, blood glucose, etc.) efficiently and accurately. Body Area Networks (BANs) consist of various sensors which gather patient's vital signs and deliver them to doctor's .The health information can be recorded in a local database. Data stored at database is send to fuzzy logic controller to improve accuracy and amount of data to be sent to the remote users.The paper presents a novel approach for body monitoring system using rule based sensor networks with the help of fuzzy logic.**

Keywords: Wireless Body Area Networks, Fuzzification, Defuzzification, rule based systems, inference engine.

I. INTRODUCTION

In general, WBASNs are wireless networks that support the use of biomedical sensors and are characterized by: very low transmitting power to coexist with other medical equipment's and provide efficient energy consumption; high data rate so that they can allow applications with high quality of service constraints; low cost, low complexity and miniature size to allow real feasibility [1].

Sensors are heterogeneous, and all these sensors integrate into the human body. The number and type of sensors vary from one patient to another depending on the state of patient. The most common types of sensors are the "EEG" which is used to measure the electrical activity produced by the brain, the " Electrocardiogram (ECG)" which is used to record the electrical activity of the heart over the time, the "Electromyography (EMG)" which is used to evaluate physiological properties of muscles, blood pressure, heart rate, glucose monitor, the pulse oximetry (SpO2) which is used to measure the level of oxygen saturation in the blood, to measure temperature of the body, respiration and motion etc. in such networks different kind of sensors are attached on the clothing or on the body or even implanted under the skin. In this case the patients do not need to be physically present at the physician clinic for their routine diagnostic to check if they are equipped with WBASN.

II. WIRELESS BODY AREA SENSOR NETWORKS

ARCHITECTURE

AWBASN architecture is shown in figure 1. It consist of sensor nodes, a coordinator and communication channels for transmitting gathered signal information over a wireless network to control the centre [2,3]. The classification of nodes in WBASNs based on their role in the network is as follows [2]:

Coordinator: The coordinator node is like a gateway to the outside world, other WBASNs, a trust centre or an access coordinator. The coordinator of a WBASN is the personal digital assistant through which all the other nodes communicate.

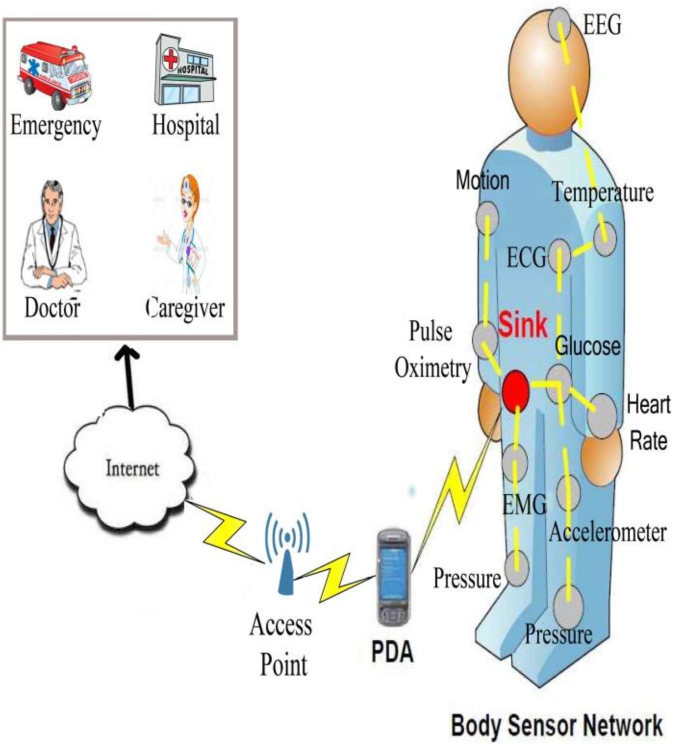

Fig. 1 Wireless Body Area Sensor Network Architecture

Sensor: It measures certain parameters in one's body either internally or externally. These nodes gather and respond to the data on the physical stimulus and process necessary data. Some existing types of these sensors could be used in one's wrist watch, smart mobile phones and consequently allow wireless monitoring of a person anywhere, anytime and with anybody. The wireless sensor nodes collect information of a body, relay it through the coordinator and store the biological information on the data centre through the communication infrastructure.

A WBSAN system can be divided into two schemes. In one scheme all sensors transmit the signal directly to the coordinator via one hop and in another scheme the sensors transmit the signal to the coordinator via multiple hoops [4].

In this the two commonly used topologies are Star Topology and Cluster based Topology.

In star topology the sensors use high power to transmit the signal because the coordinator is not always close to the sensors. Therefore the life time of the sensors becomes shorter and each sensor causes the interface to the other sensors in its area. In this case, the connection between sensors and the coordinator may fail due to the interruption of the body, especially when the human is moving. All sensors transmit the vital data toward the coordinator. In WBASN system based on the one-hop star topology, all sensors transmit its data directly to the coordinator. The vital data packet is generated at each sensor by its access probability.

In cluster based topology the sensor nodes are divided into some clusters and one node is selected as cluster head in each cluster. Since each sensor transmits the signal to the neighbouring sensor, the transmit power, the transmit area and the effective area are small. Therefore the number of interfered sensors decreases and the life time of the sensor increases. In additional, even if the direct connection between the sensors and coordinator fails, the sensor can transmit to the coordinator via other sensor that connects to the coordinator. In cluster based topology, a sensor can transmit the signal to its Cluster Head (CH) instead of the coordinator.

III. Fuzzy Logic Model

Instead of classical linear controllers or mathematical models, we introduce a fuzzy logic-basedcontroller in this article due to its simplicity, clarity and suitability with WSN applications. Fuzzysystems are very useful in situations involving a highly complex system whose behaviours are notwell understood and in situations where an approximate, but fast, solution is warranted. Fig. 2 shows the structure of a general fuzzy logic system(FLS). The fuzzifier converts the crisp input variables x ε X, where X is the set of possible input variables, to fuzzylinguistic variables by applying the corresponding membershipfunctions. Zadeh defines linguistic variables as ‘‘variableswhose values are not numbers but words orsentences in a natural or artificial language’’ [5]. An inputvariable can be associated with one or more fuzzy setsdepending on the calculated membership degrees. Forexample, a temperature value can be classified as bothLow and Medium.

The fuzzified values are processed by if–then statementsaccording to a set of predefined rules derived from domainknowledge provided by experts. In this stage the inferencescheme maps input fuzzy sets to output fuzzy sets. Finally,the defuzzifier computes a crisp result from the fuzzy setsoutput by the rules. The crisp output value represents thecontrol actions that should be taken. The above three stepsare called fuzzification, decision making, and defuzzification,respectively. We describe each of them in more detailin the following subsections.

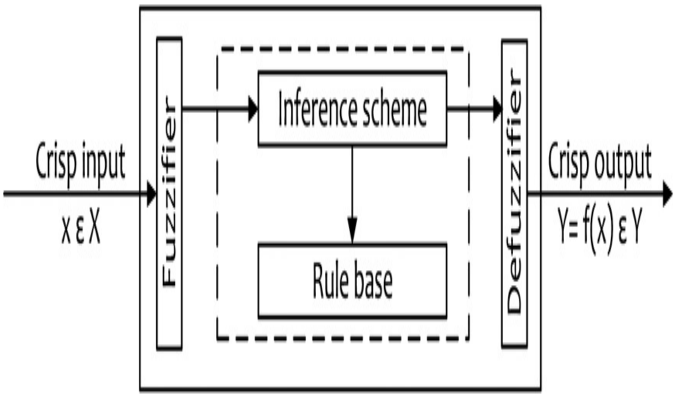

Figure 2.Fuzzy logic controller structure.

Fuzzification: The fuzzifier converts a crisp value into degrees ofmembership by applying the corresponding membershipfunctions. A membership function determines the certaintywith which a crisp value is associated with a specificlinguistic value. The membership functions canhave different shapes. Some of the most frequently usedshapes include triangular, trapezoidal, and Gaussianshaped.Membership functions are defined by either relyingon domain knowledge or through the application ofdifferent learning techniques, such as neural networks.

Decision Making: A rule-base consists of a set of linguistic statements,called rules. These rules are of the form IF premise, THENconsequent where the premise is composed of fuzzy inputvariables connected by logical functions (e.g. AND, OR, NOT)and the consequent is a fuzzy output variable. The rule-baseis usually generated as an exhaustive set of all possible value-combinations for the input linguistic variables thatconstitute the premise. Similarly to how membership functionsare defined, the rule-base is derived either based ondomain knowledge, or through using machine learningtechniques.

Defuzzification: Executing the rules in the rule-base generates multipleshapes representing the modified membership functions.For example, a set of rules designed to decide the probabilitythat there is a fire may produce the following result:

Low (56%), Medium (31%), and High (13%).

Defuzzificationis the transformation of this set of percentages into a singlecrisp value. Based on how they perform this transformation,defuzzifiers are divided into a number of categories.The most commonly used defuzzifiers are centre of gravity,centre of singleton, and maximum methods:

The centre of gravity approach finds the centroid of theshape obtained by superimposing the shapes resultingfrom applying the rules. The output of the defuzzifieris the x-coordinate of this centroid.

The defuzzification process can be significantly simplifiedif the centre of singleton method is used. With thismethod, the membership functions for each rule aredefuzzified separately. Each membership function isreduced to a singleton which represents the function'scentre of gravity. The simplification consists in thatthe singletons can be determined during the design ofthe system. The centre of singleton method is anapproximation of the centre of gravity method.

Although experiments have shown that there are slightdifferences between these two approaches, in mostcases the differences can be neglected.

The class of maximum methods determines the outputby selecting the membership function with the maximumvalue. If the maximum is a range, either the lower,upper, or the middle value is taken for the output valuedepending on the method. Using these methods, therule with the maximum activity always determines theoutput value. Applying this approach to the aforementionedfire detection example will produce a decisionthat there is a Low probability of fire and the otherfuzzy values will be automatically ignored. Since the class of maximum methods shows discontinuous outputon continuous input, these methods are not consideredto be very suitable for use in controllers.

IV. Proposed System

The proposed wireless body sensor network for health monitoring integrated into a three tier telemedicine system. The lowest level consist set of intelligent sensors or nodes. These are the reduced function devise. The second level is the personal server (Internet enabled PDA, cell-phone, or home computer). These are full function devices. The third level encompasses a network of remote server which is the remote application to which data or information is transferred.

Micro-controllers are useful to the extent that they communicate with other devices, such as sensors, motors, switches, keypads, displays, memory and even other micro-controllers.

Wearable sensors and systems have evolved to the point that they can be considered ready for clinical application. The use of wearable monitoring devices that allow continuous or intermittent monitoring of physiological signals is critical for the advancement of both the diagnosis as well as treatment of diseases. Wearable systems are totally non-obtrusive devices that allow physicians to overcome the limitations of ambulatory technology and provide a response to the need for monitoring individual's over weeks or months.

Here, we have designed a FLC system for health monitoring services, which is one of component in our pervasive computing prototype health status. The FLC system receives context information from sensor (sensor data stored in data base) equipment's as the inputs of the FLC and the fuzzification module converts inputs into fuzzy linguistic variable inputs.

The different sensors used in the proposed system are Glucose Sensor, Pressure Sensor and Heart Beat Sensor. The outputs of these sensors are applied to fuziffier after the process of normalization. The proposed Fuzzy Inference System is shown in figure no. 3.

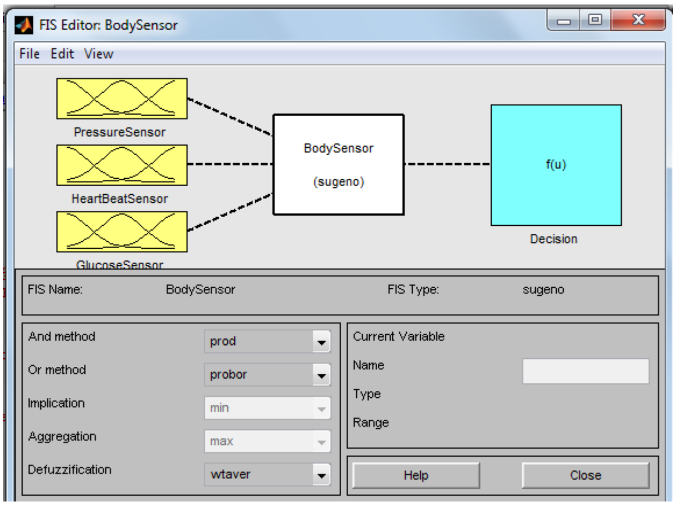

Figure no. 3 Fuzzy Inference System with Sensor Outputs

The Glucose sensor is used to monitor the glucose in the body. Every cell of the human body requires energy to perform the metabolic functions that sustain life. Glucose is a small, simple sugar that serves as a primary fuel for energy production, especially for the brain, muscles and several other body organs and tissues. Glucose also serves as a building block for larger structural molecules of the body, such as glycoproteins and glycolipids. The human body tightly regulates glucose levels. Abnormally high or low levels result in serious, potentially life-threatening complications.

The pressure sensors are used to monitor the pressure of the body.Pressure plays an important role in our health, as for example blood pressure in the human circulatory system. Blood pressure is the pressure that is exerted by blood against the walls of the arteries as it travels through the body. When the volume of blood pumped through the arteries or the pressure that the blood puts against the walls of the arteries increases, the delicate tissues in the artery walls wear thin and may tear. Fat and cholesterol deposits further obstruct blood flow, narrowing the arteries, and thereby accelerating damage by raising blood pressure even more. Elevated blood pressure speeds up the progress of atherosclerosis, and wears out the coronary arteries faster than normal. High blood pressure may cause heart failure, kidney failure, and strokes. As blood travels through the arterial system, the heart contracts and relaxes. When blood pressure is measured, two values are given. The first, called the systolic pressure, refers to the pressure on the arterial walls when the heart contracts and the second, called the diastolic pressure, is the measure of the pressure when the heart relaxes.

Heart Beat Sensors are used to measure the heartbeat of a person. A person's heartbeat is the sound of the valves in his/her's heart contracting or expanding as they force blood from one region to another. The number of times the heart beats per minute (BPM), is the heart beat rate and the beat of the heart that can be felt in any artery that lies close to the skin is the pulse. Heart rate is measured by using two numbers. The first number is called systolic heart rate which measures the pressure in our blood vessels when your heart beats. The second number is called diastolic heart rate which measures the pressure in your blood vessels when your heart rests between beats. If the measurement reads 120 systolic and 80 diastolic, you would say "120/80 mmHg." A heart rate less than 120/80 mmHg is normal. A heart rate of 140/90 mmHg or more is too high. People with levels in between 120/80 and 140/90 have a condition called prehypertension, which means they are at high risk for high heart rate.

On analyzing the data collected from the sensors, the output of the sensors are normalised to a scale of 0-10 before applying to fuzzifier. Three linguistic variables were defined, representing the physical sign of patient. The membership functions of these input parameters of the fuzzy logic are illustrated in Fig.4, 5 & 6.

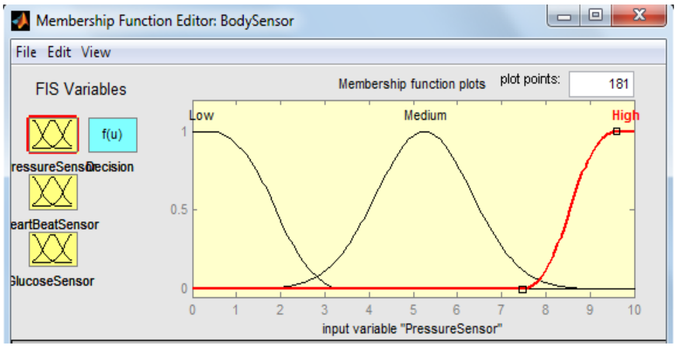

Figure no. 4 Input Variable Pressure Sensor

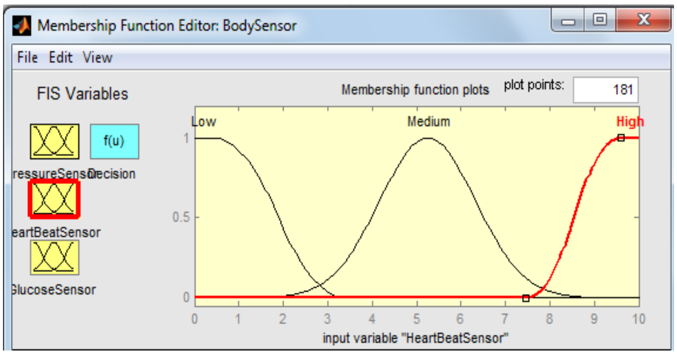

Figure no. 5 Input Variable Heart Beat Sensor

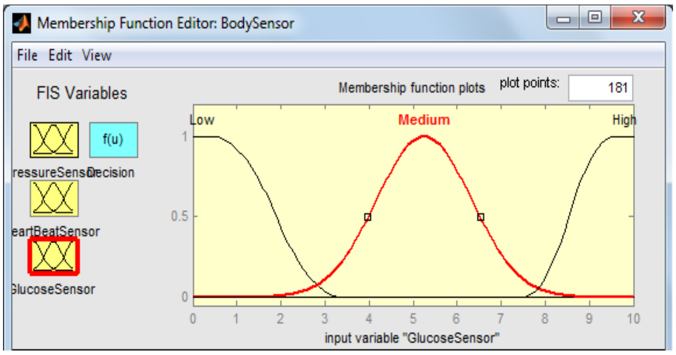

Figure no. 6 Input Variable Glucose Sensor

As there are 3 inputs to the FIS, having 3 membership function to each input so 27 rules are applied to obtain the decision. The rule block is shown in figure 7.

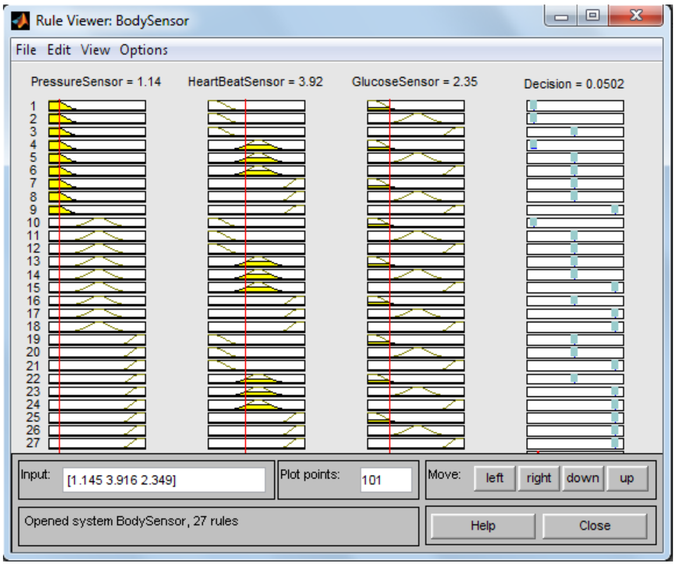

Figure no. 7 Rule Viewer for proposed FIS system

Status values are evaluated for all the health data entries recorded by the sensors and feed into the FIS system. The status value to be evaluated is based on body pressure, heart beat and glucose. The figure no. 7 shows that if the normalised values of pressure sensor, heartbeat sensor and glucose sensor are 1.14, 3.92 and 2.35 respectively then the output is 0.0502 i.e. below normal condition. The threshold values can be defined for below normal and above normal on the output scale. The threshold values can be varying from patient to patient depending upon its age and its physical health. At the age of 48, if it is assuming that the threshold values are 0.35 and 0.75 for lower and upper respectively, then the output decision for different normalised values of sensor is given in table 1.

Table 1. Different values of health data and its decision

Sr. No	Pressure	Heartbeat Rate	Glucose	Decision
1	1.14	3.92	2.35	Below Normal
2	6.45	8.01	7.77	Above Normal
3	5	3.31	4.28	Normal
4	6.69	5.48	7.05	Normal
5	1.75	1.51	7.89	Below Normal

V. CONCLUSION

The paper demonstrates the use of Wireless Body Sensor Network as a key infrastructure enabling unobtrusive, constant, and ambulatory health monitoring. This new technology has potential to tender a wide range of assistance to patients, medical personnel, and society through continuous monitoring in the ambulatory environment, early detection of abnormal conditions, supervised restoration, and potential knowledge discovery through data mining of all gathered information. This paper proves that wireless sensor networks can be widely used in healthcare applications. We believe that the role of Body sensor networks in medicine can be further enlarged and we are expecting to have a feasible and proactive prototype for wearable / implantable WBSN system, which could improve the quality of life.

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