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A Low Power Control System for Wireless Body Area Networks using Adaptive Fuzzy Logic

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Abstract: Wireless body sensor networks (WBSNs) for medical applications, such as vital signal monitoring and the diagnose assistant has received tremendous attention in recent years. Wireless sensing system tends to focus on low power consumption. Firstly, an adaptive fuzzy controller is designed and a statistical analysis of the performance of the system is conducted. An adaptive-resolution control system based on a fuzzy control technique is designed for wireless body sensor networks in order to develop a high quality and low power system. The concept of the adaptive resolution control technique is to produce the control signals by selecting different clock frequencies with fuzzy decision technique. The results show that this work can improve the quality of ECG signals in abnormal region and also reduce transmission power for wireless body sensor networks. Results prove that adaptive fuzzy logic can adapt rapidly and successfully to the changing dynamic situation with which it is presented.

Keywords: Adaptive, fuzzy logic, health care monitoring, wireless body sensor networks.

I. INTRODUCTION

Wireless Body Area Network (WBAN) in recent years has received significant attention, due to their potentiality in various applications [2]. The WBAN system can monitor physiology signals (such as body temperature, electrocardiogram (ECG), blood pressure, blood glucose, etc.) efficiently and accurately. 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.

A WBAN system can have two major advantages compared to current electronic health monitoring system. Usage of portable monitoring devices is increasing rapidly, so the first advantage is the mobility of patient due to the usage of portable devices. Second advantage is the location independent health monitoring technique.

The fuzzy logic has proven to be very effective in modeling complex systems. An adaptive fuzzy logic system not only adjusts to time conditions, but also changes the supporting system controls. The output of a fuzzy controller is derived from fuzzification of both inputs and outputs using the membership functions. In the first step of fuzzy logic based systems, the input variables are transformed to fuzzy values employing input membership functions. The fuzzy inference system (FIS) [3] provides a fuzzy output based on the rules. The last stage of this process is the defuzzification which converts obtained results into original variables using output membership functions for each output. In order to obtain better performance and results from a fuzzy logic based control system, the input/output variables, membership functions, and rule base should be carefully chosen for the functioning. The fuzzy logic can be applied to health monitoring system using wireless body sensor network for deciding final observation of patient health status based on bio-signal reading.

In this modern era health-care is a must for quality life of every individual. The population growth of developed countries and government's budget are directly proportional. This represents challenges for health based techniques. One of the important challenges is to organise health-care for the people who are living independently. Basically, health monitoring is performed on a periodic way, where the patient have to remember its symptoms; for this the doctor have to prescribe a diagnostic, then monitors the patient progress along with the treatment. Wireless sensor networks allow home health care, smart nursing homes and research augmentation for health applications. The following section focuses on various challenges before describing medical applications of WBSNs and general aspects that describe this kind of technology. The main challenges in healthcare application include that low power, limited computation, robustness and security.

II. RELATED WORK

In this section some related works have been discussed. In [4] an asynchronous micro control unit for wireless body multi-sensor networks is presented here. It consists of asynchronous interfaces, a power management unit, a multi-sensor controller, and a data encoder (DE).The asynchronous interface is created for system performance. In addition to

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that a multi sensor controller is designed for detecting the various bio signals. As a result, delay problem can be obtained.
A reconfigurable system design for wireless body sensor networks is presented in [5].It consists of an asynchronous interface, a register bank, and a reconfigurable filter. Moreover, a multi-sensor controller and a reconfigurable filter with memory were added to the MCU design for various body sensors controlling. The wireless body sensor network system having more flexibility, lower power consumptions, and higher ability to many applications by the reconfigurable control designs. But by using the reconfigurable system the complexity of the system can be increased.
A variable resolution control system [6] is created for wireless body area networks. It consists of a MCU, a variable sample rate generator, sensors, and a RF transceiver. With the limitation of power, this variable resolution WBSN system will help the doctors or hospital to monitor health conditions of the patients with more flexible and adaptive characteristics.
Many approaches exist with different design goals, but the same purpose is to provide health information to the patient using wban. In this work, the main aim is to show the health information and the WBAN system focus on low power consumption.

III. PROPOSED SYSTEM

Wireless body area networks (WBANs) are, low-powered, wireless communications network of sensors and components that is in vicinity of the human body. For better mobility and accessibility, the sensors can be embedded in clothing, medical patches, wearable devices and implants. These sensors can communicate wirelessly to a controller that will transmit the data to the hospital which can be monitored by doctors .Wireless body area networks can provide efficient and effective health monitoring of patients in hospitals and home care environment.
Fuzzy-logic theory has been applied to many industrial issues including production systems [7]. The main attentions have been given to modelling the scheduling problems within a fuzzy frame. Many fuzzy logic based scheduling systems have been developed, although it is difficult to make the comparisons between them due to their different thoughts and implementations. Fuzzy Logic offers several similar features that make it a particularly better choice for many control problems.
Fuzzy inference systems (FIS) is a way of mapping an input value to an output value using fuzzy logic system.This uses IF-THEN statements for the fuzzy rules. The IF part is mainly used to capture information by using the conditions, and the THEN part can be utilized to give the output in linguistic variable form. The system consists of a fuzzification, a knowledge base, fuzzy inference system and defuzzification. The fuzzification converts classical inputs (crisp values) into fuzzy variables. The knowledge base consists of a database and rule base. IF-THEN rules are the rule base used in the fuzzy logic .The database defines the membership functions of the fuzzy sets. Fuzzy inference engine is used to combine membership functions with the control rules to derive the fuzzy output. The defuzzification converts the processed fuzzy variables back into original values. Fuzzy Logic does not require precise inputs, it is robust, and can process any reasonable number of inputs.

A. System Architecture
Wireless body sensor node act as a basic element in a WBAN system. Fig 1 depicted the block diagram of a wireless body sensor node. This includes an adaptive controller, a phase lock loop (PLL), two down-sample circuits, a RF transmitter, and an antenna.

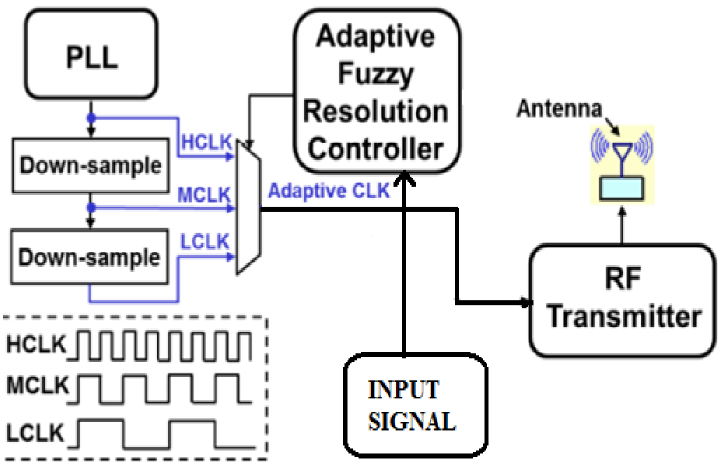

Fig.1. Block diagram of a wireless body sensor node

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Adaptive Fuzzy Resolution Controller is the main part of the system. First, it compares the amplitude of the signals values with the window conditions, as shown in Fig. 2. After that, it calculates the variance between the current and the previous values which is defined in Eq. 2. After getting the variance, the input parameter "g" can be obtained. At last, the adaptive fuzzy resolution controller can select the clock signal from HCLK, MCLK, or LCLK according to the input parameters "f" and "g" values.
The down-sampling circuit is a digital circuit used to down sample the signals in order to obtain the MCLK and LCLK.The PLL produces the HCLK and the counter counts integer number of HCLK. It triggers an output register to produce MCLK signal. Likewise, the LCLK can be obtained by down-sampling from MCLK. The frequency of MCLK and LCLK can be obtained by the frequency division of HCLK.
The input signal is MIT-BIH Arrhythmia database. In order to show the performance of adaptive fuzzy resolution system, this input ECG signal is used.

B. Fuzzy Control Technique
Fuzzy logic provides an efficient methodology to handle the concept of partial truth. A fuzzy logic control technique based on if- then rules are created for adaptive resolution control system, in order to improve the performance of the adaptive resolution control. Each rule illustrates the relation between input and output fuzzy sets. User can set the rules, functions, and parameters of the fuzzy logic control according to the specific needs. And also users can use various parameters and fuzzy rules to produce the good fuzzy logic control models.
The inputs are the absolute value of f (n) and slope value of g(n), as presented in Eq. (1) and (2), were selected as fuzzy parameters.
The main parameters of the fuzzy logic control in this example are defined as follow:

$$f(n) = abs(P(n)) \quad (1)$$

$$g(n) = abs(P(n) - P(n-1)) \quad (2)$$

Where P (n) is amplitude of ECG signal.

The two window-conditions of the adaptive resolution fuzzy control technique include a high-level window-condition and a low-level window-condition. The high-level window-condition comprises of high-level plus and high-level minus, in this the high-level plus is the maximum value of the high-level window-condition while the high-level minus is the minimum value of the high-level window-condition. The users can set the resolution conditions for some specific applications by using the two window-conditions.

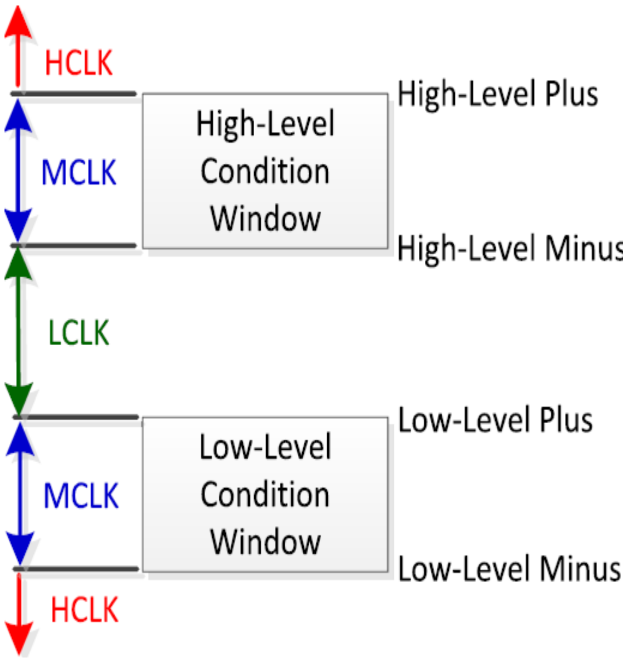

Fig 2.Two window-conditions of the adaptive resolution control.

Some of important concern that has been taken into account for determining the rules are as follows. The Adaptive_CLK is selected as HCLK when the values of the ECG signal are out of the window-condition as shown in fig 2. For example, if g is Very Low and f is Very Low then the clock is selected as HCLK or if g is Very High and f is Very High then the clock is selected as HCLK. Next case the Adaptive_CLK is selected as MCLK when the variations

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and values of the ECG signal are both within the windows-condition as shown in fig 2. For example, if g is Medium and f is Medium then the clock is MCLK. Table 1 tabulated the fuzzy adjustment rule table for the frequency of the clock. It maps the two input fuzzy sets to output fuzzy sets.

Table 1 Fuzzy adjustment rules for the frequency of the clock.

f \ g	Very Low	Low	Medium	High	Very High
Very Low	HCLK	LCLK	LCLK	LCLK	HCLK
Low	HCLK	LCLK	LCLK	LCLK	HCLK
Medium	HCLK	MCLK	MCLK	MCLK	HCLK
High	HCLK	HCLK	HCLK	HCLK	HCLK
Very High	HCLK	HCLK	HCLK	HCLK	HCLK

IV. ANALYSIS AND RESULTS

The two window condition of the adaptive resolution control system can be obtained by the fuzzy logic. By using this logic the following high, medium, and low levels thresholding can be implemented.

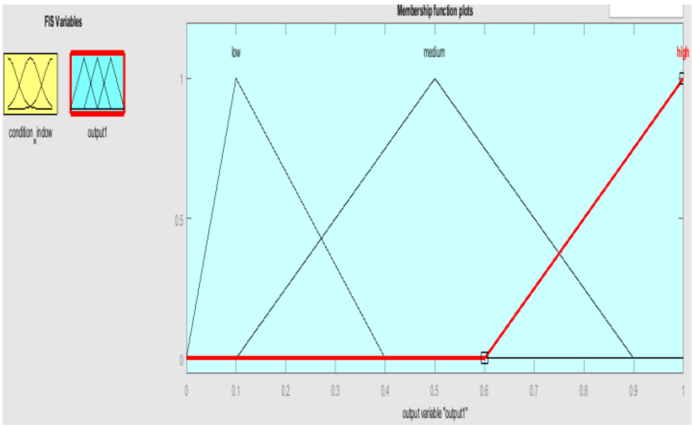

Fig 3(a) membership function plots

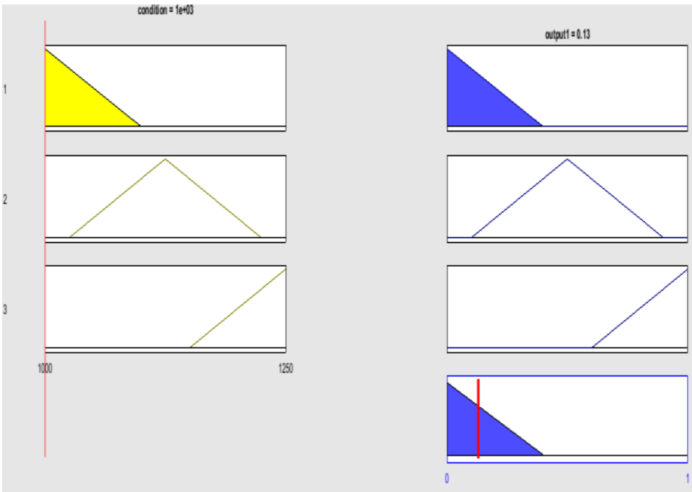

Fig 3(b) low-level output of the condition window

And also adaptive fuzzy control system is used for the wireless body area networks, which results in low power consumption. In the previous work, the data rates and power consumptions were increased with the sampling rate. According to the previous work, it consumes 16.3mW power to transmit a bit through a transmitter. Thus for the adaptive fuzzy control system consumes only 14.39mW power.

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V. CONCLUSION

A new method adaptive control system using fuzzy logic had been presented for a wireless body area network (WBAN). For WBAN, along with wireless body sensor node an adaptive fuzzy resolution controller was added for better performance. The results show that this can improve the quality of ECG signals in abnormal region. It also reduces the transmission power for wireless body sensor networks. And also the proposed adaptive fuzzy resolution control system has the characteristics of low-power, high-performance, and cost efficiency.

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