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Walking stick with Heart Attack Detection

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ABSTRACT: The Walking Stick with Heart Attack Detection is equipment that is used daily to indicate heart condition, to detect heart attack and to call for emergency help.It was designed specially to help senior citizens and patients with heart disease.It consists of three basic sub projects Ecg Circuit, Analysis Algorithm and Bluetooth Communication. The first unit is worn on the user's wrist captures abnormal heart beat signal from the patient., and the rest two are installed in the stick..The microcontroller on the stick runs a heart attack algorithm. Warning is given out

KEYWORDS: Heart attack algorithm; Electrocardiogram (ECG),Biosensors,Picmicrocontrollers

I. INTRODUCTION

The National Heart, Lung, and Blood Institute states that "more than 3million persons in the India have a heart attack and about half of them die in each year. About one-half of those who die do so within 1 hour of the start of symptoms and before reaching the hospital". A heart attack happens to a person when the blood flow and oxygen supply to heart muscle is blocked, and it is mostly caused by the Coronary Artery Disease (CAD).CAD occurs when the arteries that supply blood to the heart muscle (coronary arteries) become hardened and narrowed .It often causes irregular heart beat or rhythm by blocking blood stream .The National Heart, Lung, and Blood Institute suggest that "everyone should know the warning signs of a heart attack and how to get emergency help".

The symptoms of heart attack can be detected by observing electrocardiogram (ECG) to the person about his heart condition. The Bluetooth emergency calling system calls for medical help at the moment of heart attack. The effectiveness of the proposed method is confirmed by experiments on a commercially available walking stick.Each of the three subprojects responded positively. The proposed Walking Stick with Heart Attack Detection is cost effective and can save the lives of millions of old people by helping them in getting the earliest medical help in the condition of heart attack.

An ECG is an electrical recording of the heart and is used in the investigation of heart disease. An electrical impulse initiates muscle contraction, which results in heart beating. The spacing between pulses provides a measure of the heart's rhythm, whereas the height of the pulses is an indicator of pumping strength. By observing the ECG waveform, the heart condition of the patients can be explained by doctors.

The ECG Library shows many samples of abnormal ECG waveform, and they are mostly collected from aged people who are more than 55 years old .The senior citizens are more prone to have heart attack than young people. The Walking Stick with Heart Attack Detection is specially designed to help the senior citizens who need walking aids by walking sticks and have the most possibility of heart attack. The walking stick is used as detection unit and as the medium asking for medical help.

In [2] authors used average residual battery level of the entire network and it was calculated by adding two fields to the RREQ packet header of a on-demand routing algorithm i) average residual battery energy of the nodes on the path ii) number of hops that the RREQ packet has passed through. According to their equation retransmission time is proportional to residual battery energy. Those nodes having more battery energy than the average energy will be selected because its retransmission time will be less. Small hop count is selected at the stage when most of the nodes have same retransmission time. Individual battery power of a node is considered as a metric to prolong the network lifetime in [3].

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Authors used an optimization function which considers nature of the packet, size of the packet and distance between the nodes, number of hops and transmission time are also considered for optimization. In [4] initial population for Genetic Algorithm has been computed from the multicast group which has a set of paths from source to destination and the calculated lifetime of each path. Lifetime of the path is used as a fitness function. Fitness function will select the highest chromosomes which is having highest lifetime. Cross over and mutation operators are used to enhance the selection. In [5] authors improved AODV protocol by implementing a balanced energy consumption idea into route discovery process. RREQ message will be forwarded when the nodes have sufficient amount of energy to transmit the message otherwise message will be dropped. This condition will be checked with threshold value which is dynamically changing. It allows a node with over used battery to refuse to route the traffic in order to prolong the network life. In [6] Authors had modified the route table of AODV adding power factor field. Only active nodes can take part in rout selection and remaining nodes can be idle.

The lifetime of a node is calculated and transmitted along with Hello packets. In [7] authors considered the individual battery power of the node and number of hops, as the large number of hops will help in reducing the range of the transmission power. Route discovery has been done in the same way as being done in on-demand routing algorithms. After packet has been reached to the destination, destination will wait for time δt and collects all the packets. After time δt it calls the optimization function to select the path and send RREP. Optimization function uses the individual node's battery energy; if node is having low energy level then optimization function will not use that node.

1.1. Overview of Design

The ECG circuitry unit on the wrist captures abnormal heart beat signal from the patient. The microcontroller on the stick runs a heart attack algorithm. Warning is given out to the person about his heart condition. The Bluetooth emergency calling system calls for medical help at the moment of heart attack. This project aims to shorten the time between the moment of heart attack and the arrival of medical personal. The warning before the emergency call will give the patient a chance to avoid heart attack. Two biosensors worn on the user's wrists send the real ECG signal to the analog ECG circuitry. The amplified and filtered analog output of the circuitry is converted from analog to digital signal and transmitted to the unit on the walking stick. The ECG circuitry unit, the A/D converter, and the transmitter are worn on one of the user's wrists. The wireless connection between the unit on the wrist and the main unit on the walking stick gives the user more freedom to move by Specifications:

For the design of the ECG circuitry and the ECG algorithm, the specifications of the previous project "Wireless Heart Attack Detector with GPS" were used.The frequency range of ECG signal depends on the activity of individual. The typical range is approximately from 50 Hz to 70 Hz. To cover a wide range of frequencies for all scenarios, the band-pass filter of the ECG circuitry is designed to have a lower cutoff frequency of 0.5 Hz and an upper the A/D conversion operates properly. The overall avoiding wire attachment between the wrist and the stick. cutoff frequency of 150 Hz. The analog output of the ECG circuitry must be in the range between -2 V to 2V so that that the A/D conversion operates properly.

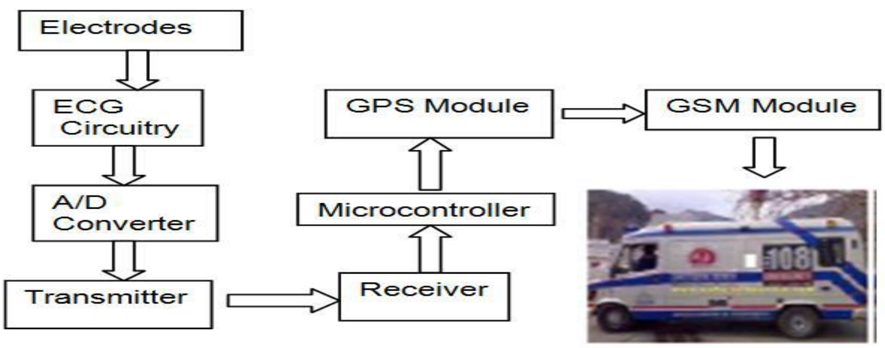

Figure: Block diagram of walking stick with Heart Attack detection

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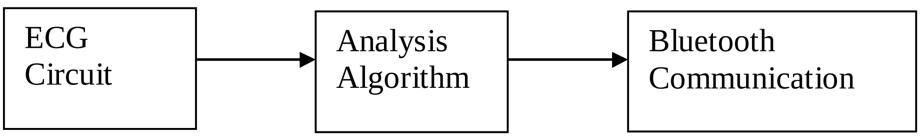
The receiver on the stick receives the digital ECG signal, and the microcontroller runs a heart attack algorithm to detect possible heart attack symptoms. If any symptom of heart attack is detected, the risk level rises. When the risk level reaches up to the emergency mode, the Bluetooth module activates the user's mobile phone to call 911 for medical help. Latest mobile phones include GPS function.amplification inside the ECG circuitry should be at least 3000 but no greater than 5000.

The minimum sampling rate of A/D converter should be 400 Hz to capture the detailed ECG waveform that changes in millisecond unit . The transmitted data and the received data must be the same. No noise should be added during the transmission. The distance for reliable transmission should be wide enough so that the movement of user is not limited in the near area of the stick. 40 feet is chosen as the user is assumed to be within this distance during all his activities.All the hardware should operate with low power consumption, and the microcontroller must show the least number of error when it runs the heart attack algorithm. High risk and low risk warnings should be shown when symptoms are detected. The delay time between the moment of heart attack detection and the activation of Bluetooth module should be as short as possible.

1.2 Performance Benchmarks:

The total delay from the moment the microcontroller output a heart attack signal to the arrival of medical assistance should be shortened as much as possible. This delay is between the output of heart attack signal and the mobile phone calling. The delay time should be less than 45 seconds



II. DESIGN PROCEDURE

2.1 Biosensors

Since the previous project mentioned about the benefits of the Ag-AgCl ECG electrodes, we decided to use the same electrodes as our biosensors. The benefits of the electrodes include good electrical contact with human skin, low motion artifacts and strong adhesive quality to skin.

2.2 Analog ECG Circuitry

Based on the "Wireless Heart Attack Detector with GPS", we designed the three components, unity-gain buffers, differential amplifier and band-pass filter. The unity-gain buffers are needed for both wrists as impedance transformers. Although skin impedance is high, the input impedance of op-amps is infinity and the op-amps will be able to catch the bio signals out of the two electrodes. Differential amplifier will take the two bio signals and differentiate them with gain to get the desired ECG waveform. Band-pass filter will make sure that noise of frequencies outside 0.5 Hz and 150 Hz is eliminated. For the Calculation of the ECG circuitry design, the same procedure from the "Wireless Heart Attack Detector with GPS" was used and was quoted as below.The differential amplifier gain should not exceed 33 in order to prevent a 300 mV electrode offset potential from causing the system to saturate.

2.3 Data Transmission between Wrist and the Walking Stick

Our original design was to transmit the analog ECG waveform directly out of the ECG analog circuitry to the walking stick. We would use the analog signal transmission capability of the HP-3 transceiver. We wanted to make this data transmission wireless from the wrist to the stick. This would avoid the inconvenience of the stick attachment to the wrist. User can go into a car and put his stick at the back seats without detaching any wire between his wrist and the stick. He also does not have to switch the device off. When the stick falls down, it won't drag the user's wrist to the ground. After we browsed through the data sheet of the HP-3 transceiver, we discovered that the analog bandwidth of the transceiver pair is between 50 Hz and 28000 Hz. ,normal ECG waveform has frequency range between 50 Hz and 70 Hz. However, to cover all the possible scenarios like sleeping and fast walking, the lower and the upper cutoff

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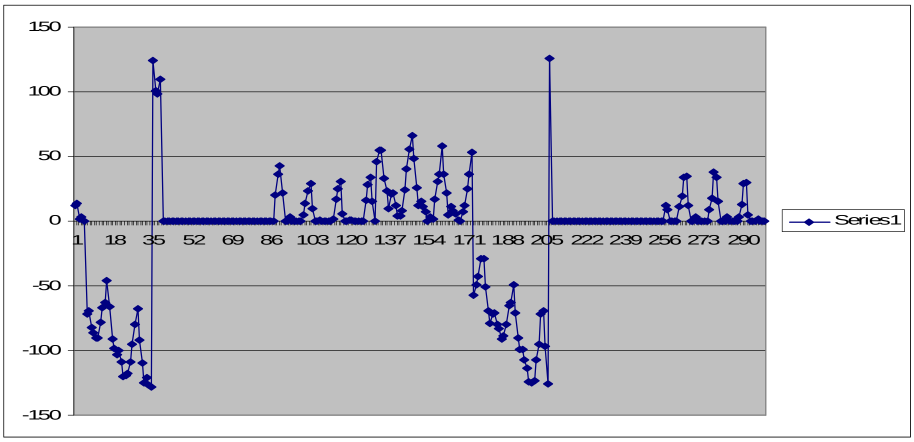
frequencies were decided to be 0.5 Hz and 150 Hz. Since the range from 0.5 Hz and 50 Hz is outside the transmission bandwidth of the HP-3 transceiver, we thought about using mixer and oscillator to raise the lowest frequency of analog signal, which is 0.5 Hz, to 60 Hz. This would ensure correct transmission of the analog signal.

We here introduce the RS232 capability of PIC. Since RS232 signal is digital, we can use the same transceiver to transmit digital signal. We no longer have to worry about the lowest frequency of the analog signal along with the mixer and the oscillator.

Below Figure:Sample Normal ECG Waveforms(These samples were collected from team members)



2.4 A/D Conversion of Analog ECG Signal to Digital ECG signal

Since we are using a PIC for its RS232 feature, we thought it would be natural to use the A/D conversion feature of the PIC. We then had to decide between using an 8-bit conversion or a 10-bit conversion. 10-bit conversion would give higher resolution to the digitized ECG waveform. But, the final decision was determined by the RS232 transmission. According to the PIC-C Compiler Manual, when defining #use RS232, bits sent can only be between 5 and 9. Because 10 are not in this range, we decided to do 8-bit A/D conversion.

2.5HeartAttackDetection

When the microcontroller on the walking stick has received digital ECG data from the wrists, it will check for heart attack symptoms. We decided to use the heart attack algorithm developed by the previous project. We would like to indicate to the user his heart condition so that he can take proper action like slowing down or taking a rest before heart attack really happens to him..

2.6 Emergency Calling

This project will execute emergency calling with just a Bluetooth module. Bluetooth communication is wireless. The user can put his cell phone anywhere he wants as long as it is within the range of the Bluetooth communication. The user does not have to hang his cell phone to the walking stick, making his waking stick heavy and hindering his movement.

III. DESIGN DETAILS

3.1 A/D Conversion and RS232 of PIC16F877

We use PIC16F877 as our microcontroller on the wrist. The connections to the PIC are shown in Appendix 1. Oscillator of 20 MHz is used as clock to the PIC. Analog ECG signal is sent to Pin2 RA0. Pin4 $Vref^-$ is connected to 0 V and Pin5 $Vref^+$ is connected to 5 V. The analog signal will be digitized into 8 bits. The digital values will be between 0 and 127. 0 V will correspond to 0, 1 V will correspond to 50, 2 V will correspond to 100 and 2.5 V will correspond to 125. Since the analog ECG waveform will be amplified to only 2 V, the highest digital value will be 100. The reason of not amplifying the signal to 2.5 V is to provide some error of margin in the real world. The sampling will be done with

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a while loop that runs continuously with the condition always set to 'true'.The sampling rate of 400 Hz will be implemented by putting a delay of 2500 us in the while loop. After the digital values are obtained through the A/D conversion, the digital values are parallel 8 bits. These parallel 8 bits will be transformed into serial bits of the format of RS232. According to Wikipedia, RS-232 is a standard for serial binary data interchange between a DTE (Data Terminal Equipment) and a DCE(Data Communication Equipment) .In our case, the DTE will be the PIC and the DCE will be the HP-3 transmitter. The RS232 format will consist of a 'start' bit, eight data bits, least-significant bit first, and a 'stop' bit. We also make sure the logic voltage level of RS232 will be between 0 V and 5 V as required by the HP-3 transmitter.

3.2 Digital Data Transmission of HP-3 Transceiver

The digital ECG values in RS232 form will be fed into a HP-3 transmitter. HP-3 transmitter has 8 parallel selectable channels. To have simple wiring, we selected channel 0 as we only needed to ground the three 'channel select' pins. We are also well aware that the HP-3 transmitter does not encode or packetize the data in any manner. This will assure us that the RS232 data sent from the PIC will be the same RS232 data received at the receiver. The microcontroller at the walking stick does not have to do any decoding.

3.3 Heart Attack Algorithm of the Javelin Stamp Microcontroller

The RS232 digital ECG data will be fed from the HP-3 receiver to the Javelin microcontroller. The parameters of the UART of the microcontroller are set up according to those of the PIC. The microcontroller will then get the correct digital ECG from the PIC.These digital ECG samples will be analyzed with the heart attack algorithm developed by the previous project. Heart attack is preceded by three notable symptoms, which are weak pulse amplitude, irregular heart beat and widened QRS pulse. To check for weak amplitude, a baseline is set up by averaging all the data points. Pulse amplitude is considered as weak if it is below 50% of the baseline. Normal pulse rate is between 35 bpm (beats per minute) and 200 bpm. If the digital ECG data indicates a pulse rate outside of this range, then irregular heart beat is detected. Normal pulse width is less than 36 ms. If the digital ECG data indicates a pulse width more than 36 ms, then QRS pulse has widened.

3.4 Low-Risk and High-Risk LEDs of Heart Attack

In this project, we decided to use this alert level to define two conditions, low-risk and high-risk. Low risk is when the alert level is between 4 and 6. High risk is when the alert level is between 7 and 9. These two conditions will be indicated to the user with two LEDs. User can look at the LEDs and be aware of his heart condition to take proper action to avoid the fatal moment.

3.5 EB500 Bluetooth Module and Javelin Stamp Microcontroller

When the alert level reaches 10, emergency calling through the user's cell phone will be executed. In our project, the emergency calling will be done with only the Bluetooth module and the Javelin microcontroller. Laptop will not be used as an intermediate between Bluetooth module and the cell phone. When the Bluetooth module is first powered up, it is in command mode. Communication between the Bluetooth module and the microcontroller will be done in the form of UART.

Microcontroller will send some commands to the Bluetooth module to set up a Bluetooth connection with the user's cell phone. When the connection is successfully set up, which is indicated by the LED on the Bluetooth module, the module automatically switches to data mode. A successful Bluetooth connection is nothing more than a wireless serial cable. In data mode, everything sent by the Javelin microcontroller will be received by the cell phone.
Commands to control a phone are called AT commands.

AT commands direct a phone to dial (D), answer (A) and hang up (H). Every AT command starts with "AT" (Attention). This is the command line prefix. To make a 911 call, the following command will be sent by the microcontroller to the cell phone, "ATD911;\r". The last character, "\r" is carriage return. The command means "Attention: Dialing 911". The number 911 can be replaced by any phone number.
Since most cell phones today have the GPS feature, the location of the user can be discovered and faster medical help can be sent to the spot.

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IV. DESIGN VERIFICATION /TESTING

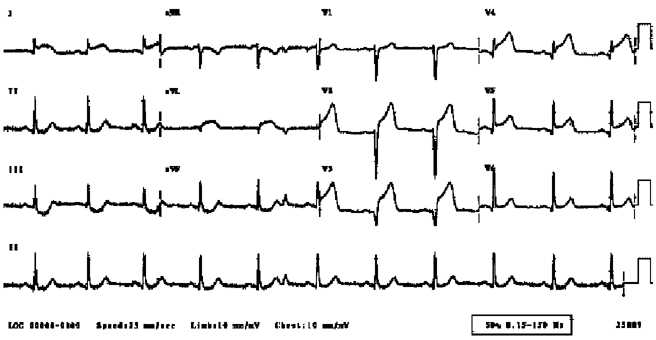
4.1 A/D Conversion:

To test the A/D conversion of the PIC, we would input a known voltage level and check the corresponding digital values.Here is our test result.

Known Voltage Level	Digital Value
0.1 V	5
1.0 V	50
2.0 V	100
2.5 V	125

4.2 RS232 of the PIC:

We tested the RS232 transmission pin of the PIC by the oscilloscope. The scope showed TTL signal between 0 V and 5 V. The signal was like a square wave.



The rectangle of the above ECG waveforms indicates weak amplitude.The circle of the above ECG waveforms indicates widened QRS pulse width

4.3 ECG Data Collection and Wireless Transmission between Wrists and the Stick

To test the ability to obtain ECG waveform and the reliability of the data transmission between wrists and the stick, we displayed digital data received by the Javelin microcontroller on the monitor and plotted the data points in Excel.

4.4 Heart Attack Algorithm

One of the ECG samples was stored in the Javelin's memory. The data points were modified in terms of amplitude, pulse rate and pulse width. The Javelin was programmed to run with this modified data. Each of the three symptoms responded positively.

4.5 Alert Level

To test the low-risk and the high-risk LEDs, we used the same modified data. We displayed the alert level on the monitor and watched the LEDs. When the alert level on the monitor was between 4 and 6, the low risk LED

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4.6 Emergency Calling

A 63 year old woman with 10 hours of chest pain and sweating. For testing , we changed the phone number to 2173335257, Which is the lab phone numbers. shone accordingly. When the alert level on the monitor was between 7 and 9, the high risk LED shone accordingly.We used the same modified data to trigger the alert level to rise above 9. When we did The LED on the Bluetooth module light up accordingly, the Ericsson T610 cell phone's screen showed the message "Dialing 2173335257" and the lab phone rang accordingly.

4.7 Power Consumption

The power consumption of the unit worn on wrist is 0.046 W. The power consumption of the unit on the stick is 0.465 W when Bluetooth module is not activated. The unit consumes 0.575 W when Bluetooth module is activated

4.8 Weight

The weight of the wrist unit is measured to be 2.88 oz without batteries. The weight will be 3.4 oz with batteries. The weight of the stick unit is measured to be 4.4 oz without batteries. The weight will be 6.4 oz with batteries.

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