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Continuous Heart Rate Monitoring System as an IoT edge device

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Abstract: *Detection of atrial fibrillation is done by checking the variations in the period of the heart rate, if a patient has atrial fibrillation then the period between each heart beat will vary. A light-based sensor can be used to detect these variations in heart rate; this is done by using Photoplethysmography (PPG) sensor which is non-invasive. The sensor consists of a LED with a photodetector and is able to detect the variations in blood volume or blood flow in the body and directly correlates to heart rate. The detected signal needs to be amplified and filtered as the signal contains a lot of high frequency noise as well as low frequency motion artifacts. The benefits of compact low-cost Wi-Fi module can be harnessed to develop a wireless continuous heart rate monitoring system enhancing possibility of atrial fibrillation detection.*

I. Introduction

Photoplethysmography refers to the non-invasive measurement of blood volume in a specified region (wrist). The volume of blood in a specified region increases in the systole phase and decreases in the diastole phase during the cardiac cycle of the heart. This changing blood volume can be directly used to calculate the heart rate and also to measure other characteristics of cardiovascular functions. It uses LEDs and their corresponding sensor as pairs in retrieving information in the form of electrical signals which a low in amplitude. This electrical signal known as the blood volume pulse signal has to be filtered from high frequency noise sources such as sunlight and ambient light, the signal also contains low frequency noise in the form of motion artifacts. The high frequency noise can be eliminated from the signal completely with the help of an active low pass filter. Most of the low frequency noise contributed by the motion artifacts can be eliminated with the use of a passive high pass filter.

The problem with motion artifacts is that they overlap with the blood volume pulse and is difficult to get rid of completely. To get rid of the motion artifacts completely more complex methods will have to implement such as Discrete Saturation Transform, Adaptive Noise Cancellation etc. This project will not try to completely get rid of motion artifacts as this is an on-going research area which has not yet found a comprehensive solution as yet. After the filtering and amplification stage the signal is fed to a microcontroller where the heart rate will be calculated and the period between heart beats will be analyzed to determine the presence of atrial fibrillation. Interfacing the controller with a Wi-Fi module allows the transfer of the measured PPG signal and heart rate provided an access point (AP) with internet. A vast number of physical object are given internet access using a small and low power Wi-Fi module hence realizing the concept of Internet of Things (IoT) which refers to the interconnection of “things” and can integrate wireless sensor network with the internet [12]. The application of IoT in healthcare can provide a consequent improvement in healthcare by exploiting its wireless nature as well as the mostly preferred cloud computing and analytics offered by the IoT platform. An alternative to this method is the photoplethysmographic (PPG) technique used in existing pulse-oximeters. A none invasive method of continuous heart rate monitoring coupled with internet access via a Wi-Fi module allows the wireless monitoring annexed with the cloud computing platform of IoT can offer the possibility of detecting atrial fibrillation for the PPG sensor wearers in the healthcare context where it is assumed little movement during the measuring period in an initial phase.

II. Methodology

A. Heart rate measurement Photoplethysmography is a method used to determine and register the variations in blood volume or blood flow in the body. This is achieved by directing light to the surface of the skin (finger, wrist) which is absorbed differently by various bodies like pigments in the skin, bone and arterial and venous blood [1].

The arterioles and arteries is where the changes in blood flow are significant. For instance, during the systolic phase the arteries contain more blood volume than the diastolic phase. Therefore, the amount of light absorbed by the blood during the systolic phase is higher than in the diastolic phase, PPG sensors optically detect these variations, by Transmission system the LED and photodetector (PD) are on opposite ends, light transmitted through the medium, whereas in reflectance system light detected by the PD is back scattered from tissue, bone and vessels [2].

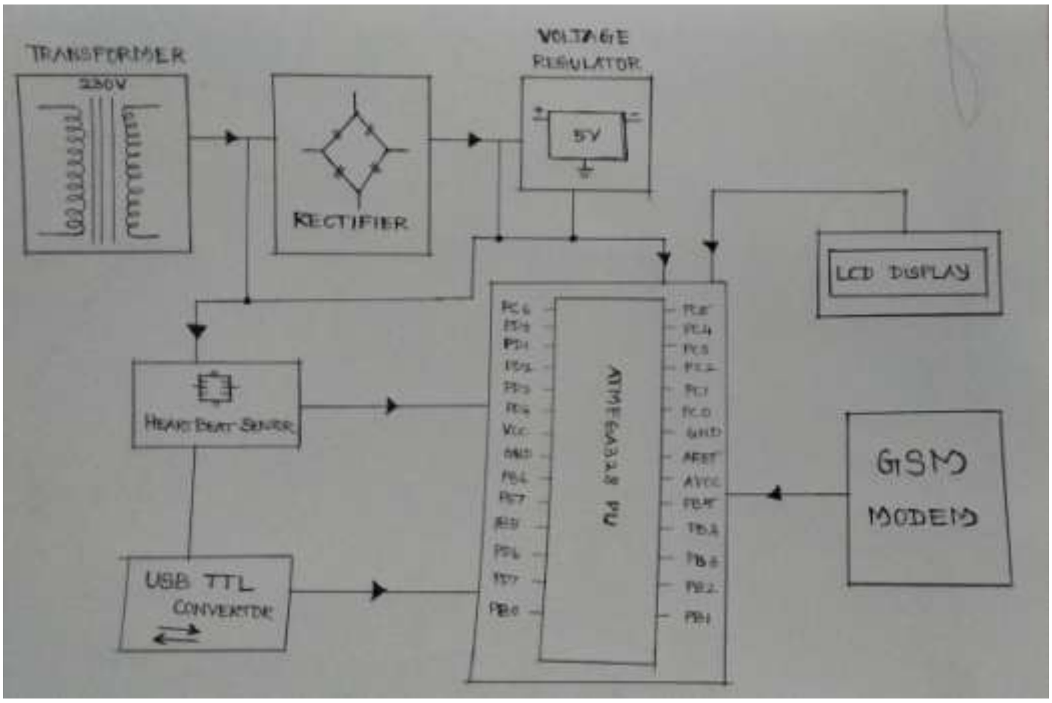


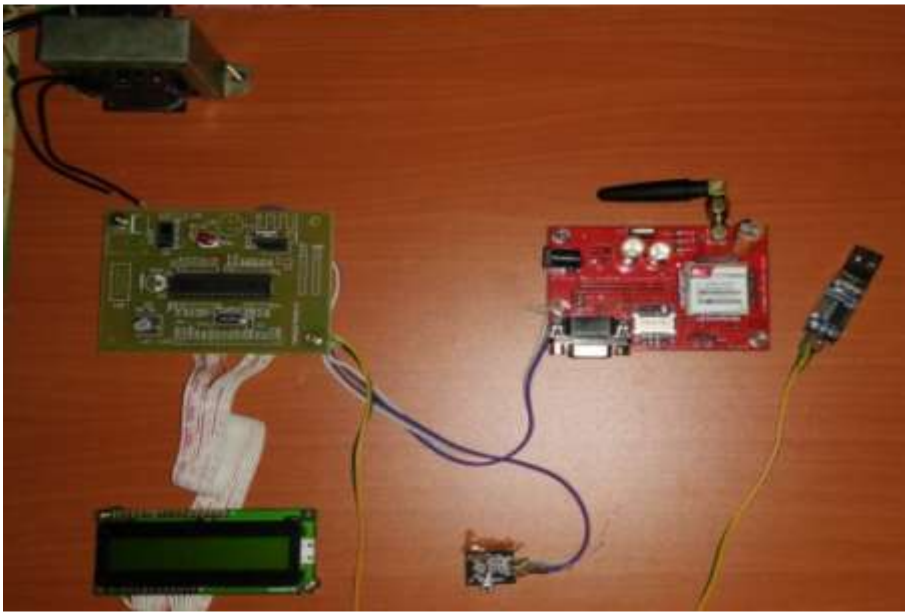
Figure of IOT based using microcontroller

A 3mm LED (Product code: DS-LED-3NG) of normal brightness (Luminous Intensity: 100-200 mcd) with a forward voltage of 2-2.5 V DC which is capable of transmitting light in 520 nm (greenlight) is chosen to construct the PPG sensor [3]. The photodiode used will be a Vishay Silicon Photodiode (BPW21R) which has a peak sensitivity wavelength at 565 nm

a rapid upward rise in signal occurs as the pulse wave under the sensor, then the signal falls back down toward the normal point. Sometimes, the dicrotic notch (downward spike) is more pronounced than others, but generally the signal settles down to background noise before the next pulse. Since the wave is repeating and predictable we can choose any recognisable feature as a reference point, in this case the peak, and measure the heart rate by doing math on the time between each peak. However, this can run into false readings from the dicrotic notch and from baseline noise as well. To test the system a subject's heart rate was measured and recorded while at rest with the PPG sensor and MI Band then the subject was asked to go down and up 5 floors of stairs soon after heart rate was measured and recorded on both devices. Next, the subject was asked to rest for 10 minutes to recover from the exercise and again heart rate was measured and recorded on both devices. This was repeated for two more subjects for a total of 3 subjects, to make the test more reliable it was conducted on individuals with different body mass index (BMI). The consensus is that individuals with high BMI will have a higher resting heart rate and the recovery heart rate or the rate at which heart beats after strenuous activity will take longer to fall.

III. Results and Discussion

After all the components were bought and tested for defects was complete, the next step was to build the sensor and its following circuitry. It was found that when following the preliminary filtering and amplification circuit acquiring the PPG signal was not possible as there was no output detected. Further research into the matter showed that an extra stage, current to voltage conversion achieved by employing a transimpedance amplifier, was required in between the photodiode biasing and high pass filter [8]. Before the system can be used to detect heart rate arrhythmia, it was first tested to see whether the heart rate measurement was reliable or not. As detection of arrhythmia depends on the system being able to reliably detect the peaks/beats of the heart. The time in between the peaks/beats will give us information about heart arrhythmia.



Output of using sensor snd GSM

Arrhythmia is the irregular beating of the heart; which translates to the time in between beats can be higher or lower than normal, this means that the IBI will also vary accordingly. The IBI values, which were used to calculate the instantaneous heart rate, can be plotted on a graph against time to show how much the IBI varies. The HR was calculated from the PPG signal and the transfer capability of the system was tested using the UART-Wi-Fi Passthrough Mode as mentioned. The test program namely, Socket Test, was used on a PC connected to the same AP to which the ESP8266 module is connected and the program was used to listen to the data sent from the ESP8266 module operating as the TCP client.

IV. Conclusion

Atrial fibrillation is one of the leading causes of strokes, heart failure and other heart-related complications, hence why a reliable method of detection is required to intervene before the condition worsens. One of the main objectives of this research project is to build a low-cost PPG sensor and this is achieved by using a LED-photodiode combination to emit the light and detect the reflected light. The wavelength of light used is in the range of 520 nm (green light), which penetrates the tissues deep enough to acquire the blood volume variations.

To achieve the second objective of this research study, a method for detecting heart arrhythmia was proposed. From the knowledge gained by conducting the literature review arrhythmia can be detected by checking the period between each heartbeat (IBI). Using the IBI values obtained and plotting a graph the rate of change of IBI can be examined. It was found that as the heart rate changes the IBI changes as well and this can be used to determine whether arrhythmia occurs. With the use of the ESP8266 Wi-Fi module for IoT and the PPG sensor, the detection of atrial fibrillation by the continuous monitoring of the PPG signal data can be made wirelessly and non-invasively and hence offering the IoT platform for the more powerful algorithm for atrial fibrillation detection by using IoT web Application Programming Interface (API) service for cloud analytics such as ThingSpeak.

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