TELEMEDICINE APPROACH FOR PATIENT MONITORING SYSTEM USING IOT

A PROJECT REPORT

Submitted by

SANTHINI KRISH.S **Reg No.:13BEC131**
SHALANI.A **Reg No.:13BEC135**
VISHNU PRIYA.K **Reg No.:13BEC174**

in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION

KUMARAGURU COLLEGE OF TECHNOLOGY

ANNA UNIVERSITY: CHENNAI

APRIL 2017

BONAFIDE CERTIFICATE

Certified that this project report **"TELEMEDICINE APPROACH FOR PATIENT MONITORING SYSTEM USING IOT" is the bonafide work of Ms SANTHINI KRISH.S [Reg.No: 13BEC131], Ms SHALANI.A [Reg.No: 13BEC135] and Ms VISHNU PRIYA.K [Reg.No: 13BEC174]** who carried out the project work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other project or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

SIGNATURE
Dr.S.N.SHIVAPPRIYA Ph.D.,
Assistant Professor II
PROJECT SUPERVISOR
Department of ECE
Kumaraguru College of Technology
Coimbatore-641049

SIGNATURE
Dr.K.MALARVIZHI Ph.D.,
HEAD OF THE DEPARTMENT
Department of ECE
Kumaraguru College of Technology
Coimbatore- 641049

The candidates with Register No: 13BEC131, 13BEC135, 13BEC174 are examined by us in the project viva-voce examination held on
……

INTERNAL EXAMINAR **EXTERNAL EXAMINAR**

ACKNOWLEDGEMENT

We express our sincere thanks to the Management of Kumaraguru College of Technology and Joint Correspondent **Shri.ShankarVanavarayar** for the kind support and for providing necessary facilities to carry out the project work.

We would like to express our sincere thanks to our beloved Principal **Dr.R.S.Kumar, M.E.,Ph.D.,**Kumaraguru College of Technology, who encouraged us in each and every step of the project.

We would like to thank **Dr.K.Malarvizhi, Ph.D.,** Head of the Department, Electronics and Communication Engineering, for her kind support and for providing necessary facilities to carry out the project work.

We wish to thank with everlasting gratitude to our Project Coordinator **Dr.Ramalatha Marimuthu, M.E., Ph.D.,** Department of Electronics and Communication Engineering for her consistent support throughout the course of this project work.

We are greatly privileged to express our deep sense of gratitude and heartfelt thanks to our Project Guide **Dr.S.N.SHIVAPPRIYA M.E., Ph.D.,** Department of Electronics and Communication Engineering for her expert counseling and guidance to make this project to a great deal of success and also we wish to convey our regards to all teaching and non-teaching staff of ECE Department for their help and cooperation.

Finally, we thank our parents and our family members for giving us the moral support and abundant blessings in all of our activities and our dear friends who helped us to endure our difficult times with their unfailing support and warm wishes.

ABSTRACT

Automatic health monitoring system is very useful for 24*7 monitoring of patients. The proposed system is mainly designed for the rural areas where the people don’t get frequent access to the doctors. In this project, heartbeat sensor, pressure sensor, MEMS sensor and temperature sensor are used to gather patient medical information and these data are sent to the raspberry pi. The raspberry pi processes these data and displays these values in the web page. By this method, monitoring the patient from a remote area and looking into their medical reports is made possible. There is no need for a doctor to visit the patient periodically. Web access functionality is available in the device to enable widely accessible and enhanced user interface functions for the device. Here, an Android based application with IoT is used to view the data of the patient. At the Android application level, mail is sent to respective doctor’s mail id in case of emergencies

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION:

In recent days, even the young people around the age of 35 are suffering from increase in blood pressure and sudden cardiac arrest. In such a situation, it is must to continuously monitor the heart patients. At the same time, the doctor cannot visit the patient all the time. This problem can be overcome by using the "Telemedicine approach to monitor the patient using IoT". There is no doubt that the Internet of Things is transforming the healthcare industry completely by redefining how apps, devices and people interact and connect with each other in delivering healthcare solutions. That is, IoT is constantly offering new tools as well as efficiencies that make up an integrated healthcare system with the view of ensuring patients are cared for better, health care costs are reduced significantly and treatment outcomes are improved. In this project VNC application and a web page are used to monitor the patient day and night and to send immediate emergency notification to the doctor once the patient's health goes down. This will help to reduce the risk of sudden cardiac arrest and increase in BP.

2. HARDWARE DESCRIPTION:

2.1 PROJECT DESCRIPTION:

The main aim of the project is to keenly observe the heart patients over day and night. Humans are prone to being careless and sometimes the doctors don't get time to visit the patient frequently. In this stressful and busy life, no one will know when a patient will suffer from cardiac arrest and high BP. The patient's life cannot be saved by knowing all this at the last minute. To overcome all this, it is necessary to monitor the patient over day and night and keep the doctor informed about the patient's health condition. Hence we have come up with a one-step solution with this "telemedicine approach to monitor patient using IoT"

The proposed system makes use of Raspberry Pi that is interfaced with various other sensors to monitor the patient automatically. The health condition of the patient is displayed in the web page continuously so that, the doctor will get to know about the patient's health condition. It will be helpful for him to take any immediate action once if the patient's health goes down.

2.2 BLOCK DIAGRAM:

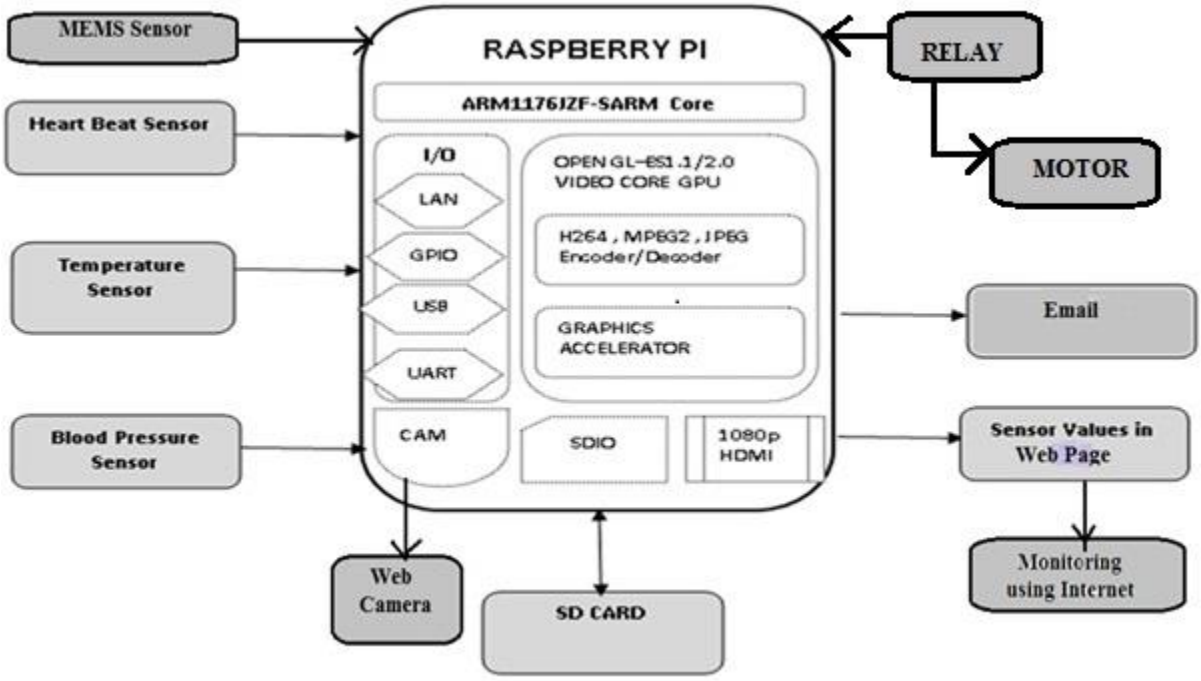

Fig: 2.1-Block Diagram

This is the block diagram of the project that we intend to implement. Block diagram is shown in fig 2.1.

- The MEMS sensor is fixed to the patient's body which detects the position of the patient whether he/she is lying flat, turning to the left or turning to the right.
- The heartbeat sensor, the pressure sensor and the temperature sensor are fixed to the patient's body which detects the pulse count, blood pressure and body temperature of the patient.
- PHP coding is written to design a web page where these sensor values get displayed. The IP address is used to access this web page from any remote

area. Web page is designed with user interface, so that the doctor can control the flow of glucose from the remote area.

- If the patient's health condition is going down, the web cam attached to the Raspberry Pi captures the image of the patient and sends an emergency alert to the doctor's mail id.

2.3 PROJECT EXECUTION PLAN:

This project requires basic prototyping of embedded system coding with the help of Raspberry Pi and python coding to interface the Pi with all other sensors and web camera. The PHP coding is used to create a web page where the patient’s health reports will get loaded. The python coding aims in bringing together the hardware and the software to achieve the necessity of making a fully automated and 24*7 health monitoring system.

Arduino can also be used for this implementation but Raspberry Pi is a mini computer that it is possible to interface more sensors compared to arduino. Arduino requires separate Wi-Fi module to be interfaced whereas, the Pi has Wi-Fi module embedded in it. All these features made Raspberry Pi very much compatible with this project.

The prototype is made into a final product by understanding the working of each sensor and coding each and every sensor based on the specifications of the Pi. The aim is to make this project cost effective by using the products and the components that are not too expensive but at the same time meeting our requirements and consuming less power thus making the system completely reliable at the same time affordable by the end users. This is the reason to use

Raspberry Pi instead of all other microcontrollers because PI is of smaller size with lot of advantages.

2.4 COMPONENTS AND ITS USES:

TABLE 1: Components and its Uses

Components	Usage/Advantage
Heartbeat sensor	To detect the pulse count of the patient
Pressure sensor	To detect the blood pressure of the patient
Temperature sensor	To sense the body temperature of the patient
MEMS sensor	To detect the position of the patient
Raspberry Pi	To Perform any real time function through coding. Here, Pi collects the data from all the sensors, processes them and displays them in the web page
Web cam	To capture the image of the patient during any emergency
Motor	To control the flow of the glucose

2.5 RASPBERRY PI:

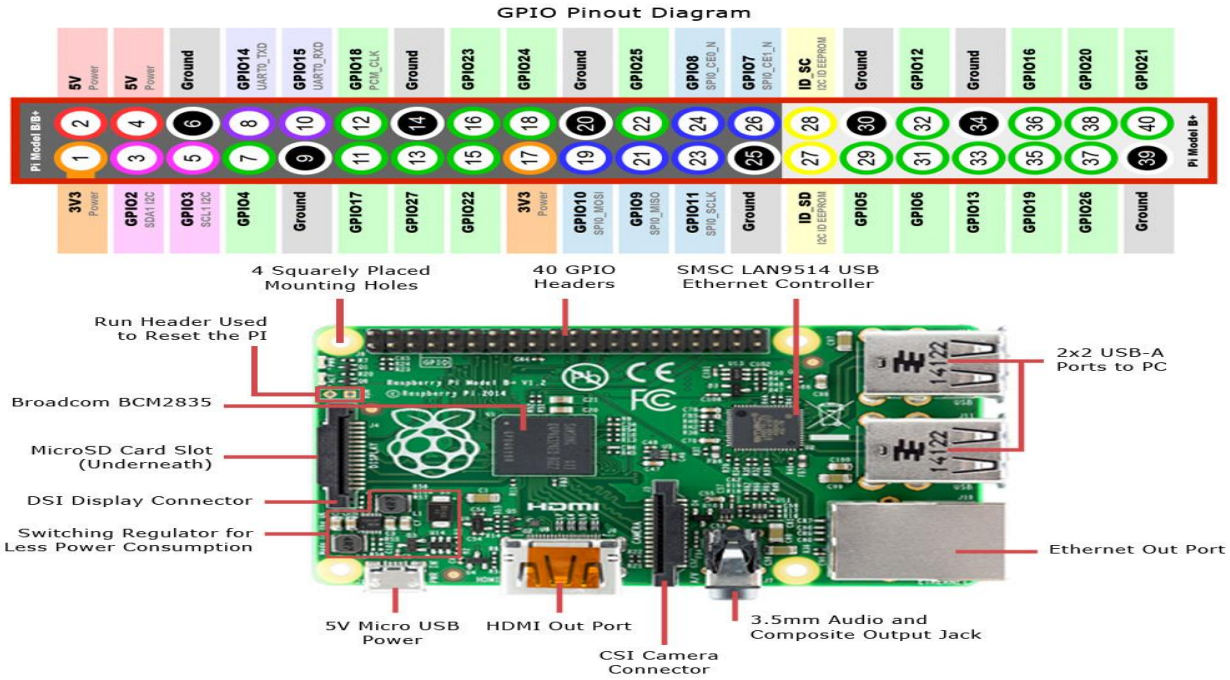

Fig: 2.2-Raspberry Pi Module

Raspberry Pi board is a miniature marvel, packing considerable computing power into a footprint no larger than a credit card. The processor at the heart of the Raspberry Pi system is a Broadcom BCM2835 system-on-chip (SoC) multimedia processor. This means that the vast majority of the system's components, including its central and graphics processing units along with the audio and communications hardware are built onto that single component hidden beneath the 256 MB memory chip at the centre of the board. It is not just, this SoC design that makes the BCM2835 different to the processor found in the desktop or laptop. It also uses a different instruction set architecture (ISA), known as ARM.

2.5.1 OPERATING SYSTEM:

The Raspberry Pi is designed to run on an operating system called GNU/Linux simply as Linux. Unlike Windows or OS X, Linux is open source. It is possible to download the source code for the entire operating system and possible to make the desired changes. This open source development has allowed Linux to be quickly altered to run on the Raspberry Pi, a process known as porting. At the time of this writing, several versions of Linux known as distributions have been ported to the Raspberry Pi's BCM2835 chip. The different distributions leads to different needs, but they all have something in common i.e all are open source.

Linux isn't exclusive to the Raspberry Pi. Hundreds of different distributions are available for desktops, laptops and even mobile devices and Google's popular Android platform is developed on top of a Linux core.

2.5.2 VIDEO:

The Pi supports three different video outputs namely composite video, HDMI video and DSI video. Composite video and HDMI video are readily accessible to the end user while DSI video requires some specialized hardware.

Composite video, available via the yellow-and-silver port at the top of the Pi known as an RCA phono connector is designed for connecting the Raspberry Pi to older display devices. The connector creates a composite of the colors found within an image red, green and blue and sends it down a single wire to the display device, typically an old cathode-ray tube (CRT) TV. The yellow RCA phono connector, for composite video output when no other display device is available, a composite video connection will get you started with the Pi. The quality isn't great. Composite video connections are significantly more prone to

interference, lack of clarity and run at a limited resolution. It can fit fewer icons and lines of text on the screen at once.

A better-quality Picture can be obtained using the HDMI (High Definition Multimedia Interface) connector, the only port found on the bottom of the Pi . Unlike the analogue composite connection, the HDMI port provides a high-speed digital connection for Pixel-perfect Pictures on both computer monitors and high-definition TV sets.

The final video output on the Pi can be found above the SD card slot on the top of the printed circuit board. It is a small ribbon connector protected by a layer of plastic. This is for a video standard known as Display Serial Interface (DSI), which is used in the flat-panel displays of tablets and smart phones.

2.5.3 AUDIO:

In the Raspberry Pi's HDMI port, audio is properly configured; the HDMI port carries both the video signal and a digital audio signal. To connect audio a single cable is connected to the display device for both sound and Pictures.

2.5.4 CONNECTING A KEYBOARD AND MOUSE

The Pi expects peripherals to be connected over the Universal Serial Bus (USB) port. Depending on the Model A or Model B, either one or two USB ports available on the right side of the Pi is used to connect the keyboard and mouse.

2.5.5 CONNECTING EXTERNAL STORAGE

While the Raspberry Pi uses an SD card for its main storage device known as a boot device, it runs into space limitations quite quickly. Although large SD cards holding 32 GB, 64 GB or more are available, they are often prohibitively expensive. But, there are devices that provide an additional hard drive to any computer when connected via a USB cable known as USB Mass Storage (UMS) devices. These can be physical hard drives, solid-state drives (SSDs) or even portable pocket-sized flash drives.

Two USB Mass Storage devices: a pen drive and an external hard drive. The majority of USB Mass Storage devices can be read by the Pi, whether or not they have existing content. In order for the Pi to be able to access these devices, their drives must be mounted.

2.5.6 INTERFACES:

The various interfaces used are heartbeat sensor, pressure sensor, temperature sensor, MEMS sensor, web camera, relay and motor. Python code is written to interface all these components with the Raspberry Pi.

2.6 LM35 - PRECISION CENTIGRADE TEMPERATURE SENSOR:

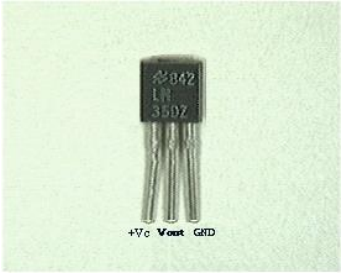

Fig: 2.3-LM35 Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55° to +150°C temperature range, while the LM35C is rated for a -40° to +110°C range (-10° with improved accuracy).

The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^{o}C).

2.6.1 ADVANTAGES:

- Temperature can be measured more accurately than using a thermistor.
- The sensor circuitry is sealed and not subjected to oxidation.
- The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.

2.7 HEARTBEAT SENSOR:

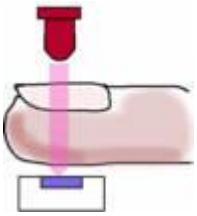

Fig: 2.4-Heartbeat Sensor

The sensor consists of a light source and photo detector; light is shone through the tissues and variation in blood volume alters the amount of light falling on the detector. The source and detector can be mounted side by side to look at changes in reflected light or on either side of a finger or earlobe to detect changes in transmitted light. The sensor uses a red LED for transmitted light illumination and a Pin photodiode as detector. With only slight changes in the preamplifier circuit the same hardware and software could be used with other illumination and detection concepts. The detector's photo current (AC Part) is converted to voltage and amplified by an inexpensive operational amplifier (LM358).

The skin may be illuminated with visible (red) or infrared LEDs using transmitted or reflected light for detection. The very small changes in reflectivity or in transmittance caused by the varying blood content of human tissue are almost invisible. Various noise sources may produce disturbance signals with amplitudes equal or even higher than the amplitude of the pulse signal. Valid pulse measurement therefore requires extensive preprocessing of the raw signal. The sensor uses a red LED for transmitted light illumination and a Pin photodiode as detector. With only slight changes in the preamplifier circuit the

same hardware and software could be used with other illumination and detection concepts. The detector's photo current (AC Part) is converted to voltage and amplified by an inexpensive operational amplifier (LM358).

2.7.1 PULSE RATE OF HUMAN AT DIFFERENT STAGES:

- Heart rate varies between individuals. At rest, an adult man has an average pulse of 72 per minute.
- Athletes normally have a lower pulse rate than less active people. Children have a higher heart rate (approx. 90 beats per minute), but also show large variations.
- The heart rate rises during exercise and returns slowly to the rest frequency after exercise. The rate at which the pulse returns to normal can be used as an indication of fitness.
- A slow heart rate is common during a heart attack. Bradycardia is a heart rate below 60 beats per minute and often with a heart attack associated with chest pain or angina.
- Tachycardia is faster than normal heart rate. Tachycardia occurs when an abnormality in heart produces raPid electrical signals. It can seriously disrupt normal heart function, increase the risk of stroke, or cause sudden cardiac arrest or death.

2.8 BLOOD PRESSURE SENSOR:

Fig: 2.5-Pressure Sensor

This sensor buffers a piezoelectric transducer. As the transducer is displaced from the mechanical neutral axis, bending creates strain within the piezoelectric element and generates voltages. If the assembly is supported by its mounting points and left to vibrate "in free space" the device will behave as a form of pressure sensor. The sensing element should not be treated as a flexible switch, and is not intended to be bent. Sensor Value 500 roughly corresponds to 0g acceleration. Acceleration will deflect the sensing element up or down, causing sensor value to swing either way.

2.8.1 FEATURES:

- Simple to install and operate
- Advanced digital signal electronics for lowest noise combined with highest sensitivity
- 0.5 Hz to 22 kHz frequency response
- Velocity up to ± 500 mm/s (3 ranges)
- Buffers a Piezoelectric transducer. As the transducer is displaced from the mechanical neutral axis, bending creates strain within the piezoelectric element and generates voltages.

2.9 3-AXIS MEMS ACCELEROMETER SENSOR:

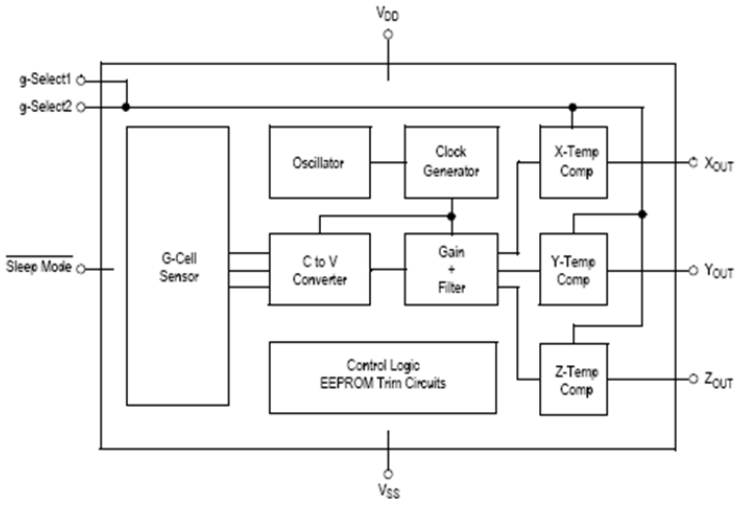

Fig: 2.6-MEMS Sensor Block Diagram

Most accelerometers are Micro-Electro-Mechanical Sensors (MEMS). The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion (**F = ma**), as an acceleration is applied to the device, a force develops which displaces the mass. The support beams act as a spring, and the fluid (usually air) trapped inside the IC acts as a damper, resulting in a second order lumped physical system. This is the source of the limited operational bandwidth and non-uniform frequency response of accelerometers.

2.9.1 FEATURES:

- High sensitivity

- Low current consumption: 500 ìA
- Low voltage operation: 2.2 V – 3.6 V
- High sensitivity (800 mV/g @ 1.5g)
- Fast turn on time
- Integral signal conditioning with low pass filter
- Robust design, high shocks survivability
- Environmentally preferred package
- Low cost

2.10 WEB CAMERA:

Fig: 2.1-Web Camera

The real time images are captured by the camera during any emergency. Web camera is interfaced with Raspberry Pi. Python code is written to capture the image of the patient whenever the pulse rate increases beyond 90 beats per minute or if the pressure increases beyond 150 mmHg or if the body temperature goes beyond 110° Fahrenheit. The captured image is attached to the mail and sent to doctor's mail id.

3. SOFTWARE DESCRIPTION:

3.1 PYTHON:

Flexible and powerful, Python was originally developed in the late 1980s at the National Research Institute for Mathematics and Computer Science by Guido van Rossum as a successor to the ABC language. Since its introduction, Python has grown in popularity to see it as a clear and expressive syntax developed with a focus on ensuring that code is readable. Python is a high-level language. This means that Python code is written in largely recognizable English, providing the Pi with commands in a manner that is quick to learn and easy to follow. This is in marked contrast to low-level languages, like assembler, which are closer to how the computer "thinks" but almost impossible for a human to follow without experience. The high-level nature and clear syntax of Python make it a valuable tool for anyone who wants to learn to program. It is also the language that is recommended by the Raspberry Pi Foundation for those looking to progress from the simple Scratch.

3.1.1 ADVANTAGES:

- Presence of third party modules
- Extensive support libraries
- Open source and community development
- Ease of learning
- User-friendly data structures
- Python has OOD that provides enhanced process control capabilities and possesses strong integration and text processing capabilities and

its own unit testing framework, all of which contribute to the increase in its speed and productivity

- It is considered a viable option for building complex multi protocol network applications

3.2 PHP TOOLS:

PHP is a server-side scripting language designed primarily for web development but also used as a general-purpose programming language. The PHP originally stood for *Personal Home Page*, but it now stands for the recursive acronym *PHP: Hypertext Preprocessor*. PHP code may be embedded into HTML or HTML5 markup, or it can be used in combination with various web template systems, web content management systems and web frameworks. PHP code is usually processed by a PHP interpreter implemented as a module in the web server or as a Common Gateway Interface (CGI) executable. The web server software combines the results of the interpreted and executed PHP code, which may be any type of data, including images, with the generated web page. PHP code may also be executed with a command-line interface (CLI) and can be used to implement standalone graphical applications.

3.2.1 ADVANTAGES:

- It can be run on many platforms, including Windows, Linux, and Mac. It is easy for users to find hosting service providers.
- Built-in database connection modules
- Powerful library support modules such as PDF, Graph, etc.,

- Since, it is maintained by many developers, bugs can be easily found and fixed
- It is open source and easy to use
- It is relatively fast since it uses much system resource

3.3 VNC APPLICATION:

In computing, Virtual Network Computing (VNC) is a graphical desktop sharing system that uses the Remote Frame Buffer protocol (RFB) to remotely control another computer. It transmits the keyboard and mouse events from one computer to another, relaying the graphical screen updates back in the other direction, over a network. VNC is platform-independent – there are clients and servers for many GUI-based operating systems. Multiple clients may connect to a VNC server at the same time. Popular uses for this technology include remote technical support and accessing files on one's work computer from one's home computer, or vice versa. VNC was originally developed at the Olivetti & Oracle Research Lab in Cambridge, United Kingdom. The original VNC source code and many modern derivatives are open source under the GNU General Public License.

In this project, VNC application is used to take the desktop access of the Raspberry Pi. On taking the desktop access, the python program is run and the output is viewed in the application. The health monitoring system is fixed to the patient’s body and the Pi's monitor is connected to this application to view the patient’s health details.

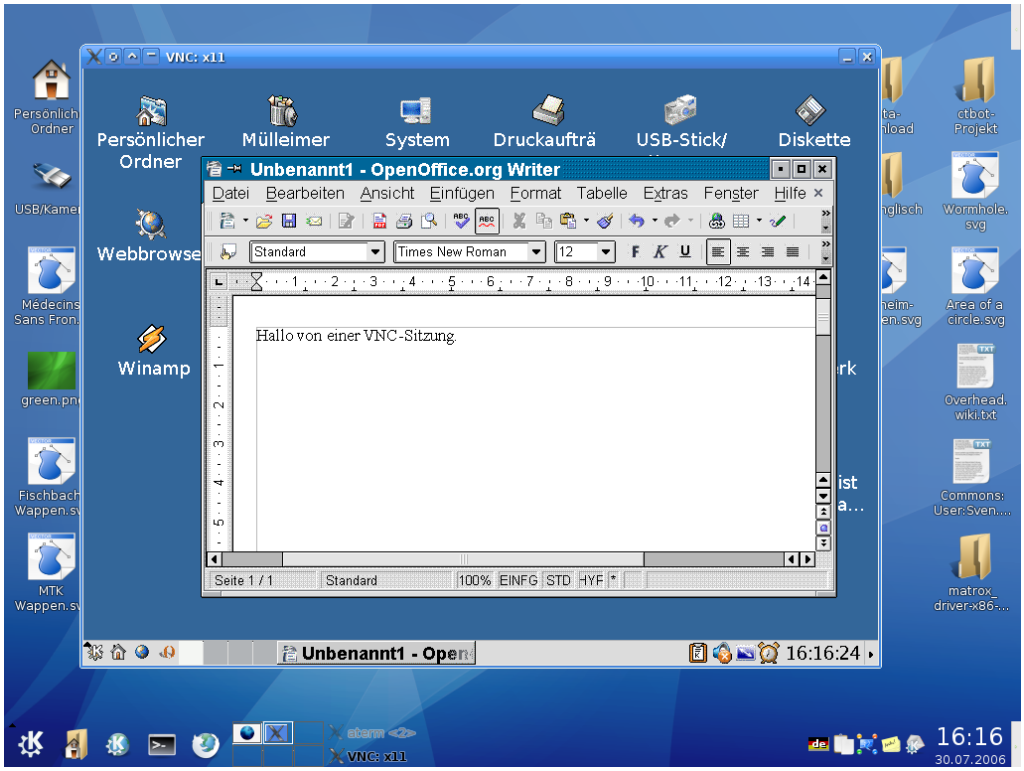

Fig: 3.1-Remote Desktop Access Using VNC App

3.4 WEB PAGE:

PHP code combined with HTML is written to create a web page. The patient's health details (the heart rate, blood pressure and the body temperature) are displayed in the web page. The doctors and any person who are concerned about the patient can view the patient's health details from a far off region through this web site. The web page is designed with the user interface. Two ON and OFF buttons will be there in the web page. These buttons are used to control the motor connected to the Pi. This motor in turn controls the flow of glucose into the patient's body. The doctor, through this web page can control the flow of glucose. A common IP address is used to access this web page. This web page can be used

from any remote location using that IP address. If the patient's health is abnormal, then the emergency alert will be displayed in the web page.

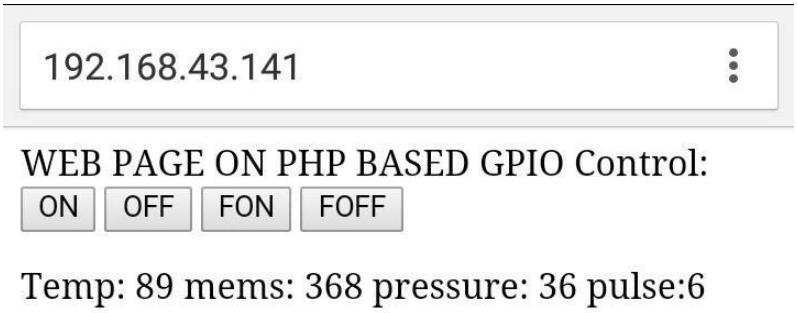

Fig: 3.2-Web Page with User Interface

4. WORKING MODEL:

The working model of the project along with all its components is shown in fig 4.1.

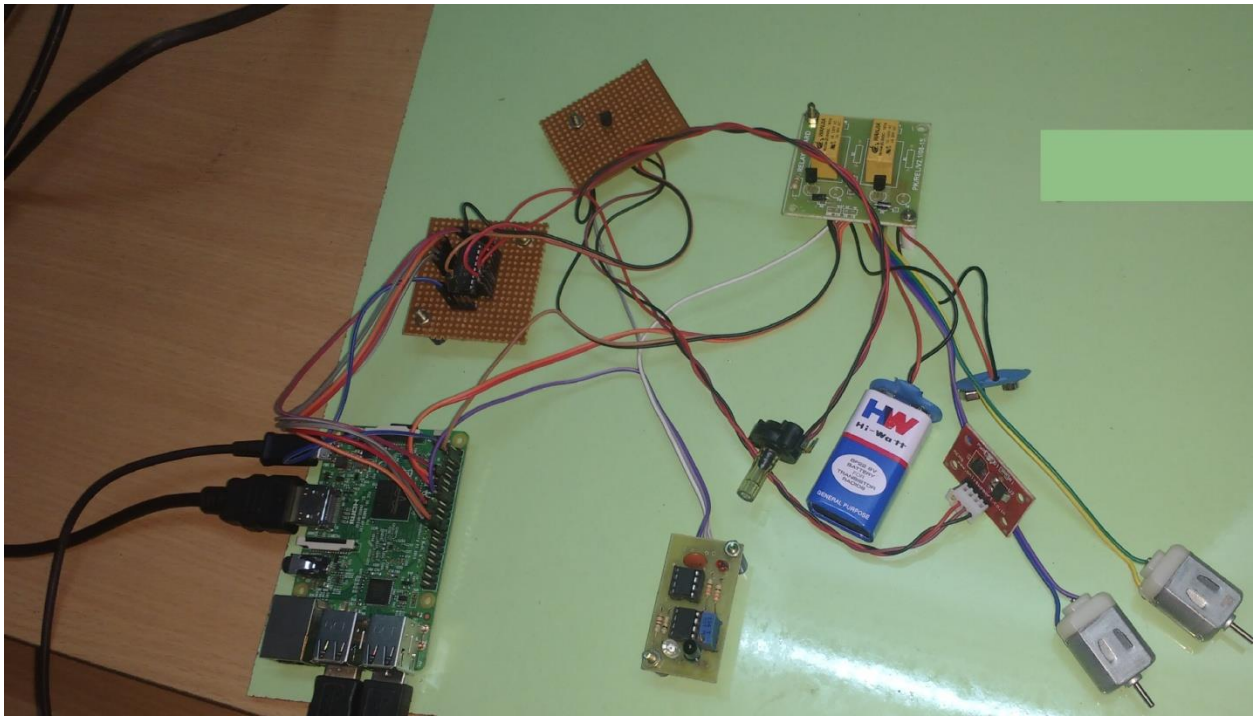

Fig 4.1- Working model

All the sensors are interfaced with the Raspberry Pi using python code. On fixing these sensors to the patient's body, the Pi starts loading the data in the web page. On any emergency condition, the mail is sent to the doctor's mail id.

4.1 SIGNIFICANCE OF THE PROJECT:

Raspberry Pi interfaced with heartbeat sensor, blood pressure sensor, MEMS sensor, temperature sensor, relay and motor and web camera is used for 24*7 monitoring of patients with heart problems and sending emergency alert to the doctor's mail id. So that, the doctor will get to know about the patient's health condition even from a far-off region.

4.2 RESULTS AND DISCUSSION:

The patients are monitored in real time and their heart rate, BP and body temperature are all tabulated. Fig 4.2 shows the image of monitoring a patient's blood pressure. The BP is sensed as 160 mmHg (Fig 4.3) which is very high and so the emergency alert is sent to the doctor's mail.

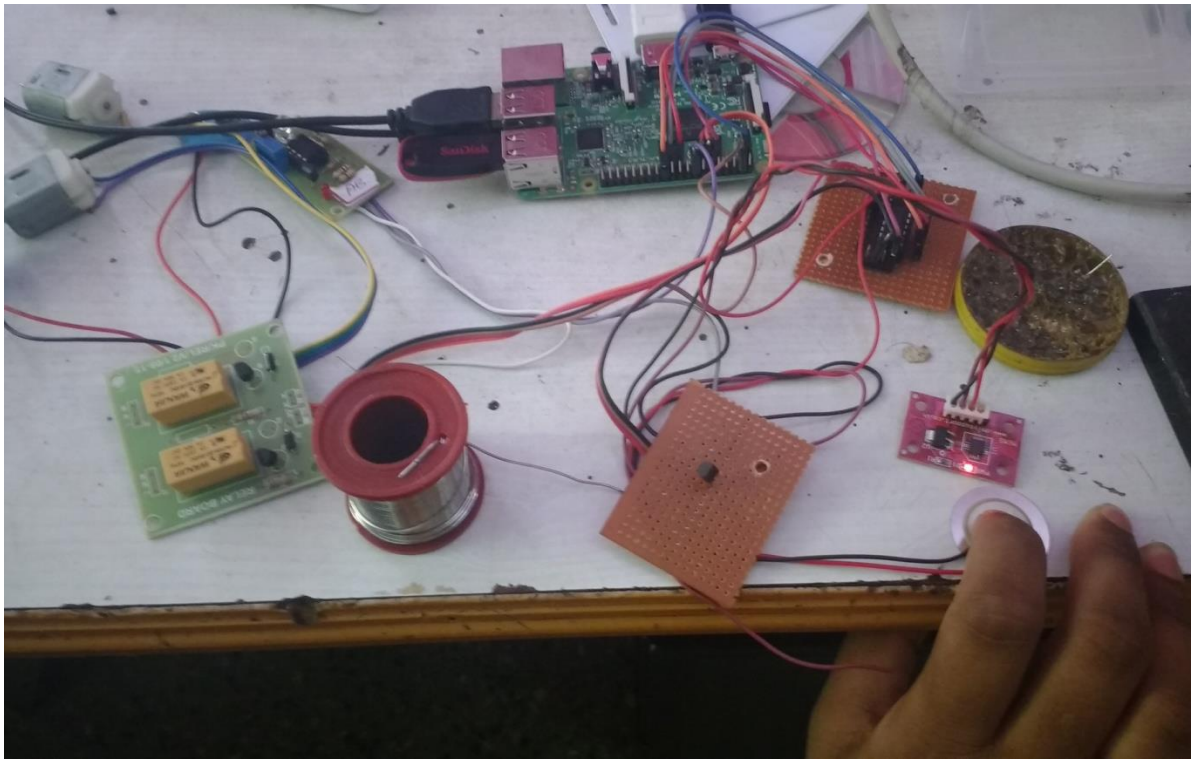

Fig 4.2- Monitoring the Pressure of the Patient

Fig 4.4 shows the image of monitoring a patient's pulse rate. The pulse rate is sensed as 69 bpm (Fig 4.5). The normal heart rate of the patient is 60 to 70 bpm.

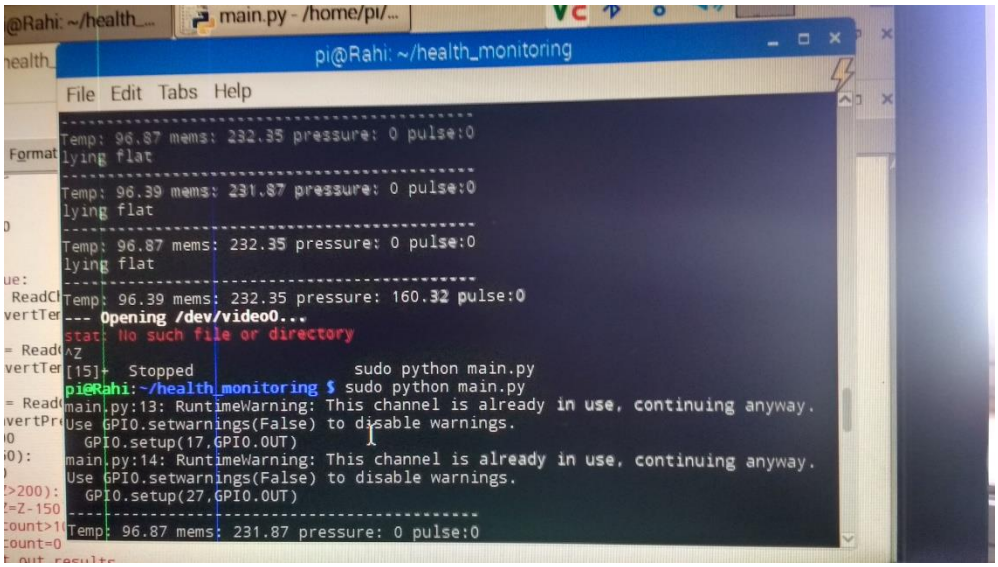

Fig 4.3- High Pressure and Emergency Alert

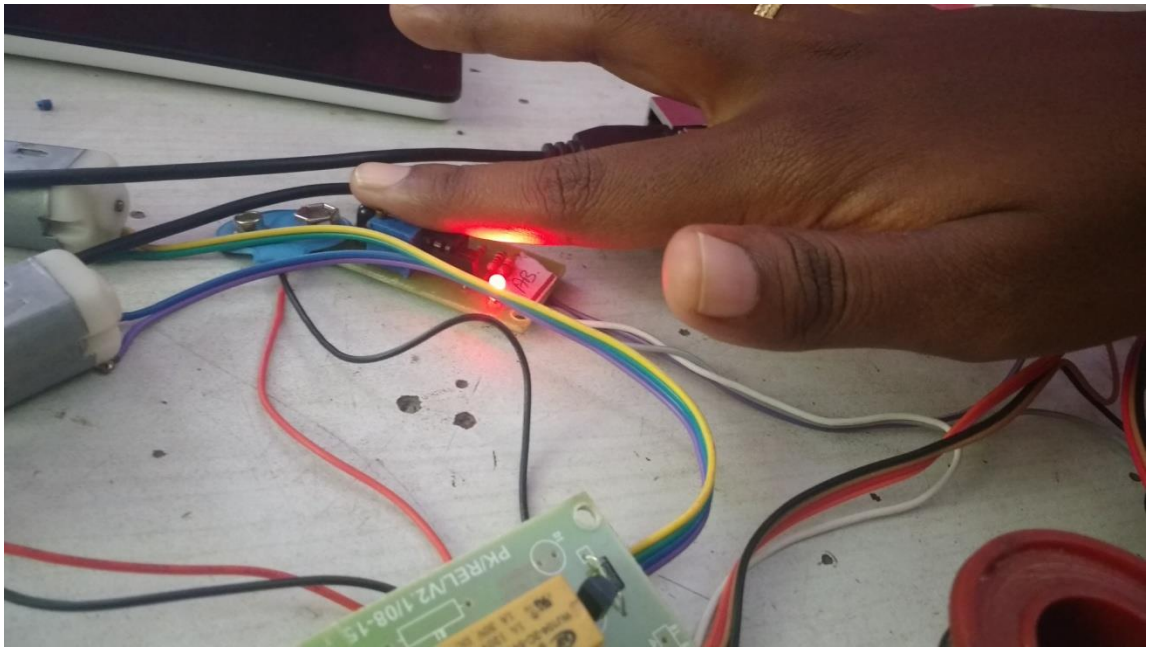

Fig 4.4- Monitoring the Pulse rate of the Patient

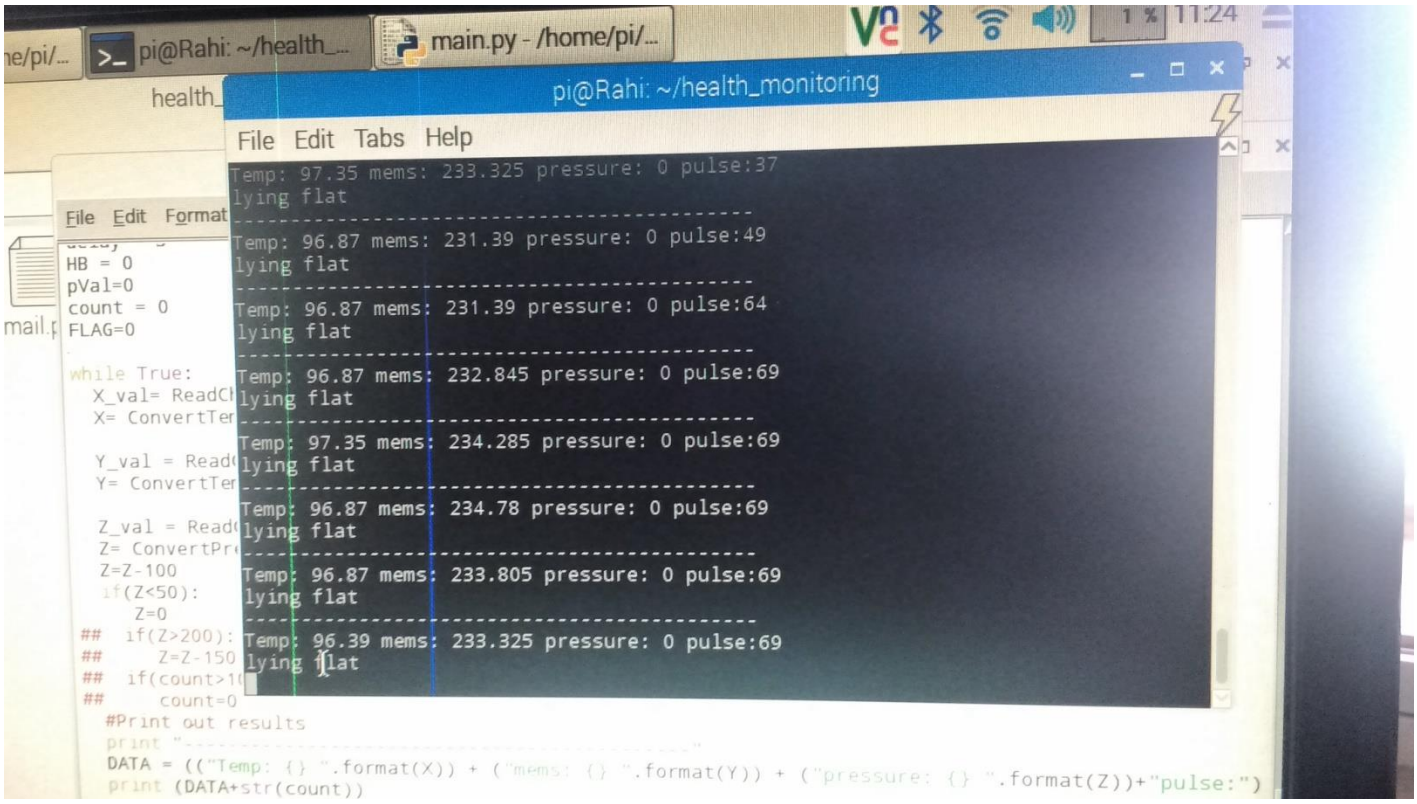

Fig 4.5- Pulse rate is measured as 69 bpm

The heart rate, blood pressure and body temperature are all monitored for 20 different patients and the values are tabulated.

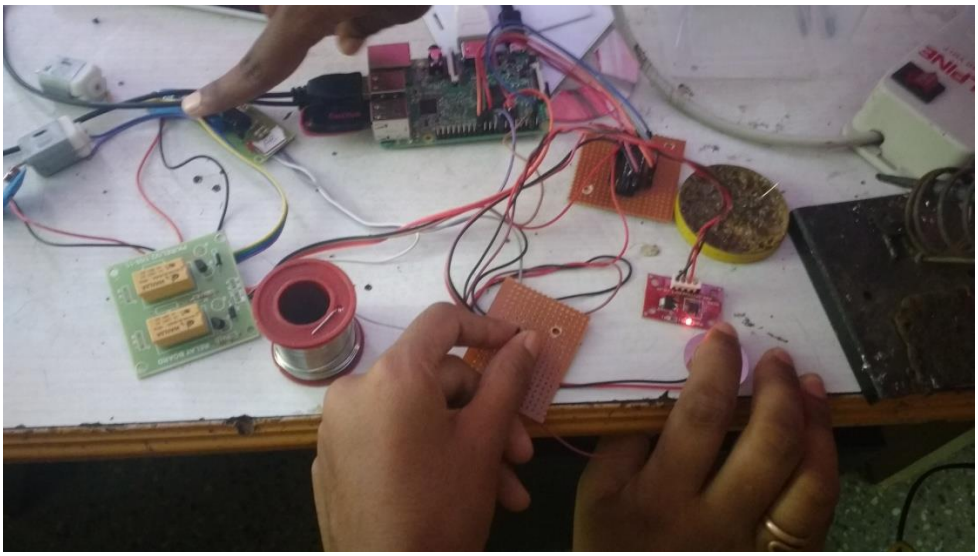

Fig 4.5- Pulse rate, BP and body temperature are monitored

TABLE 2: Monitored values of different patients

S.NO	PATIENT NAME	PULSE RATE	TEMPERATURE	PRESSURE
1	NAVEEN	73	97.88	124
2	PRAKASH	69	97.82	135
3	SANGEETHA	72	97.54	132
4	SOUNDARYA	70	98.46	144
5	PRIYA	68	97.67	156
6	DIVYA	74	99.35	150
7	VINO	69	98.80	129
8	KRISH	75	99.57	137
9	SATHYA	75	97.82	143
10	SUNIL	73	98.24	142
11	RAMYA	71	97.10	136
12	RUTHRA	72	98.50	152
13	VISALAKSHI	74	98.36	136
14	ARTHI	69	99.24	127
15	SWETHA	68	98.52	142
16	REVATHI	73	97.39	154
17	SRI	72	98.55	125
18	SABARI	71	96.77	132
19	SURYA	75	97.71	144
20	RITHU	73	98.66	148

4.2 ENHANCEMENTS OF THE PROJECT:

The further enhancement that can be made to this project is to interface any other sensors such as ECG sensor. The web camera which is interfaced to capture the patient's image during emergency can be programmed to record live video. This will make it possible to monitor the patient not only using the sensor values uploaded I the web page but also a live monitoring of the patient can be done.

5. CONCLUSION:

"Short as life is, we make it still shorter by being careless." So this project is a one step solution for 24*7 automatic monitoring of heart patient which helps the doctor with keeping track of the patient's health records even from far-off or remote areas. This new "Telemedicine approach for monitoring patient using IoT" which loads the patient's health information in the web page over day and night helps in reducing the heart patient's from facing sudden attack and death.

REFERENCES:

1. Melzer, N. Benjuya, J. Kaplanski, "Postural stability in the elderly: a comparison between fallers and non-fallers,"*Age and Ageing, Vol. 33, pp. 602-607, Nov. 2004.*

2. Asada HH, Shaltis P, Reisner A, Rhee S, Hutchinson RC,"Mobile monitoring with wearable photoplethysmographic biosensors," IEEE Eng Med Biol Mag 2003,vol 22,p.28-40.

3. Brand O,"Micro sensor integration into systems-on-chip," Proceedings of theIEEE 2006,vol 94,p.1160-1176.

4. Ahn CH, Jin-Woo C, Beaucage G, Nevin JH, Jeong-Bong L, Puntambekar A, Lee JY,"Disposable smart lab on a chip for point-of-care clinical diagnostics," Proceedings of the IEEE 2004,vol 92,p.154-173.

5. Curone D, Secco EL, Tognetti A, Loriga G, Dudnik G, Risatti M, Whyte R, Bonfiglio A, Magenes G,"Smart garments for emergency operators: the ProeTEX project. Information Technology in Biomedicine" IEEE Transactionson 2010,vol 14,p.694-701