Visvesvaraya Technological University, Belagavi.

PROJECT REPORT

on

"DETECTION OF FOOT ULCER IN DIABETIC PATIENTS"

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CERTIFICATE

This is to Certify that the dissertation work **"DETECTION OF FOOT ULCER IN DIABETIC PATIENTS"** carried out by SANDHYA RAGIKOPPA, SHRAVANI B, SUSHMA S, VANDANA C M USN: 1CR16EC149, 1CR16EC160, 1CR16EC174, 1CR16EC184 bonafide students of **CMRIT** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the academic year **2019-20**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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ABSTRACT

Healthcare and wellness management for the diabetic is one of the most promising information technology in the field of medical science. A health care monitoring system is necessary to constantly monitor diabetic patients' physiological parameters. The smart medical system focuses on the measurement and evaluation of vital parameters e.g. SPO2, electrocardiogram (ECG), heart rate variability, foot ulcer detection etc.

Diabetes brings with it neurovascular complications, which results in development of increase in pressure among the foot regions. Patients with diabetic poly neuropathy often lose pain and temperature sensations in their feet, resulting in inadequate pressure under their feet, during walking or standing. This may cause injury in the feet; painless trauma develops and results in ulceration. So prevention of diabetic foot ulcer is needed. A circuit is proposed to measure the pressure on the foot with the help of force sensing resistor.

Pulmonary Edema is a fluid accumulation in the tissue and air spaces of the lungs. It leads to impaired gas exchange and may cause respiratory failure. Pulmonary edema, especially acute, can lead to fatal respiratory distress or cardiac arrest in most of the diabetic patients. Hence this system proposes periodic measurement of heart rate and SpO2 to monitor patient's heart and lungs.

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INTRODUCTION

Chapter1

A literature review was conducted to identify the different causes of renal failure and cardiac arrest in most of the diabetic patients. It was found that the risk of death due to Cardiac arrest is Pulmonary Edema that has been increased among diabetic patients which is associated with cardiovascular disease. Diabetic patients generally develop the complications of foot ulcers, breaking down of the skin tissue in the case poorly controlled diabetics. As the numbers of diabetic patient are increasing globally with the change in the lifestyle, these ulcers can often emerge surreptitiously, with patients not noticing until it's too late. This sadly results in up to 34 percent of type II diabetics in the India ending up losing toes, a foot, or a leg. The measures for the early detection of the diabetic related problems are gaining medical importance.

1.1 Diabetes Mellitus

Diabetes is a chronic disease, which occurs when the pancreas does not produce enough insulin, or when the body cannot effectively use the insulin it produces. This leads to an increased concentration of glucose in the blood (hyperglycemia). Glucose comes from the foods we eat. Insulin is a hormone that helps the glucose get into the cells to give them energy. With type 1 diabetes, our body does not make insulin. With type 2 diabetes, the more common type, our body does not make or use insulin well. Without enough insulin, the glucose stays in our blood. One can also have prediabetes. This means that the blood sugar is higher than normal but not high enough to be called diabetes. Having prediabetes puts you at a higher risk of getting type 2 diabetes.

Over time, having too much glucose in your blood can cause serious problems. It can damage the eyes, kidneys, and nerves. Diabetes can also cause heart disease, stroke and even the need to remove a limb [11]. Pregnant women can also get diabetes, called diabetes. Blood tests can show if you have diabetes. One type of test, the A1C, can also check on how you are managing your diabetes. Exercise, weight control and sticking to your meal plan can help control your diabetes. You should also monitor your blood glucose level and take medicine if prescribed. Symptoms of diabetes include increased thirst and urination, increased hunger, fatigue, blurred vision, numbness or tingling in the feet or hands, sores that do not heal and unexplained weight loss.

Symptoms of type 1 diabetes can start quickly, in a matter of weeks. Symptoms of type 2 diabetes often develop slowly over the course of several years and can be so mild that you might not even notice them. Many people with type 2 diabetes have no symptoms. Some people do not find out they have the disease until they have diabetes-related health problems, such as blurred vision or heart trouble. Type 2 diabetes, the most common form of diabetes is caused by several factors, including lifestyle factors and genes. Type 2 diabetes used to be known as adult-onset diabetes, but today more children are being diagnosed with the disorder, probably due to the rise in childhood obesity. There's no cure for type 2 diabetes, but losing weight, eating well and exercising can help manage the disease. If diet and exercise aren't enough to manage your blood sugar well, you may also need diabetes medications or insulin therapy.

Diabetes is a growing challenge in India with estimated 8.7% diabetic population in the age group of 20 and 70 years. The rising prevalence of diabetes and other non- communicable diseases is driven by a combination of factors - rapid urbanization, sedentary lifestyles, unhealthy diets, tobacco use, and increasing life expectancy. Type 1 diabetes (earlier known as insulin-dependent or childhood-onset diabetes) is characterized by a lack of insulin production. Type 2 diabetes (earlier known as non-insulin-dependent or adult onset diabetes) is caused by the body's ineffective use of insulin. It often results from excess body weight and physical inactivity

Diabetes mellitus type 2 (also known as type 2 diabetes) is a long-term metabolic disorder that is characterized by high blood sugar, insulin resistance, and relative lack of insulin. Common symptoms include increased thirst, frequent urination, and unexplained weight loss. Symptoms may also include increased hunger, feeling tired, and sores that do not heal. Often symptoms come on slowly. Long-term complications from high blood sugar include heart disease, strokes, diabetic retinopathy which can result in blindness, kidney failure, and poor blood flow in the limbs which may lead to amputations. The sudden onset of hyperosmolar hyperglycemic state may occur; however, ketoacidosis is uncommon.

1.2 Foot Ulceration

Feet provide stability support while walking, standing and running. The foot has five major functions: it is the foundation for the whole body, it can adapt to uneven ground, it acts as a shock absorber, it provides leverage for propulsion, and it absorbs transverse leg rotation. Loss of anyone of these functions can be detrimental to the patient, and is often noticed in patients with diabetes. Foot ulceration is affecting 25% of patients with diabetes during lifetime and 85% proceeds to lower limb amputation [3]. Diabetic foot ulcer is a major complication of diabetes mellitus, and probably the major component of the diabetic foot. Wound healing is an innate mechanism of action that works reliably most of the time. A key feature of wound healing is stepwise repair of lost extracellular matrix (ECM) that forms the largest component of the dermal skin layer. But in some cases, certain disorders or physiological insult disturbs the wound healing process. Diabetes mellitus is one such metabolic disorder that impedes the normal steps of the wound healing process. Many studies show a prolonged inflammatory phase in diabetic wounds, which cause a delay in the formation of mature granulation tissue and a parallel reduction in wound tensile strength. Foot-care education combined with increased surveillance can reduce the incidence of serious foot lesions. Some of the causes of diabetic foot ulcers are High Blood Sugar Levels, Poor Circulation, Nerve Damage, Immune System Issues and Infection.

Fig 1.1 Diabetic Foot

Diabetic foot should be checked at every visit to the clinic. It is important to make a careful examination and assessment of the feet before making any decision about treatment [1]. The examination is performed for 3 sections by podiatrists.

a) Classification

The classification allocated depends on the detection of neuropathy or neuroischaemia. The foot with a combination of neuropathy and is chaemia is called neuroischaemic foot. Neuropathy means injury present in the plantar surface of foot.

b) Staging

Stage 1	Low risk foot
Stage 2	High risk foot
Stage 3	Ulcered foot
Stage 4	Infected foot
Stage 5	Necrotic foot
Stage 5	Major Amputation

Table 1.1 Stages of Foot Ulcer

c) Taking control

There are 6 different aspects of management and taking control

- Mechanical control
- Metabolic control
- Microbiological control
- Vascular control
- Wound control
- Educational control

1.2.1 Diagnostic Procedures

a) Blood Pressure

This is the first test in the diagnosis of diabetic foot ulcer. Sphygmomanometer is the instrument to measure blood pressure. The variation between systolic pressure of both right and left leg is an indication of abnormalities in foot.

b) Monofilament test

It is a simple test for sensitive evaluation, in which a thin piece of plastic fiber is touched against the various parts of the sole of your foot and ability to feel varying pressure.

c) Sensitometer Vibration Pressure Threshold

VPT technique is used to measure the sense of vibration in the foot. The threshold value is the vibration in which the patient can feel.

d) Doppler test

Doppler test is performed to check whether there is a blood flow in foot region. In this technique gel is made to spread on the foot area. Then the device is made to move on that area and the blood flow is recognized by a sound

The best strategy to avoid diabetic foot ulcers is to prevent wounds in the first place

1.3 Acute Respiratory Distress

Acute respiratory distress syndrome (ARDS) is a type of respiratory failure characterized by rapid onset of widespread inflammation in the lungs. Symptoms include shortness of breath, rapid breathing, and bluish skin coloration [9]. Pulmonary Edema is a fluid accumulation in the tissue and air spaces of the lungs. It leads to impaired gas exchange and may cause respiratory failure. It is due to either failure of the left ventricle of the heart to remove blood adequately from the pulmonary circulation (cardiogenic pulmonary edema) or an injury to the lung parenchyma or vasculature of the lung (no cardiogenic pulmonary edema). Pulmonary edema, especially acute, can lead to fatal respiratory distress or cardiac arrest in most of the diabetic patients. Congestive heart failure caused due to the heart's inability to pump the blood out of the pulmonary circulation at a sufficient rate results in elevation in wedge pressure and pulmonary edema. Diabetes can cause improper functioning of the kidney. This condition results in the accumulation of fluid in the lungs that in turn results in the reduced oxygen level in the blood thus causing respiratory distress. In critical cases this might result in cardiac arrest.

Chapter 2

LITERATURE SURVEY

[1] Screening of Foot Ulceration in Diabetic Neuropathy Patients Using Flexi Force Sensor Platform by S. Krisha Priya, A.N. Nithyaa, R. PremKumar

In this work, an experimental setup for effective screening of foot ulcer in diabetic neuropathy patients is described. Diabetes brings with it neurovascular complications, which results in development of increase in pressure among the foot regions. Patients with diabetic poly neuropathy often lose pain and temperature sensations in their feet, resulting in inadequate pressure under their feet, during walking or standing. This may cause injury in the feet; painless trauma develops and results in ulceration. So prevention of diabetic foot ulcer is needed. A circuit is proposed to measure the pressure on the foot with the help of force sensing resistor. The pressure on the foot is acquired by the sensor. For large scale data acquisition system, a graphical program environment like Lab VIEW is needed. According to the Normalized Peak Pressure (KPa) values Classification of normal and diabetic neuropathy patients was done. In this method diagnosis of foot ulceration is done in an earlier stage thereby the further ulceration is prevented.

[2] Robert G. Frykberg, Thomas Zgonis, David G. Armstrong, Vickie R. Driver, John M. Giurini, DPM,5 Steven R. Kravitz, Adam S. Landsman, Lawrence A. Lavery, J. Christopher Moore, John M. Schuberth, Dane K. Wukich, CharlesAndersen, and John V. Vanore, - Diabetic Foot Disorder-A Clinical Practice,

The new SUDOSCAN™ device is designed to perform a precise evaluation of sweat gland function based on sweat chloride concentrations using reverse iontophoresis and chronoamperometry. Measurements are performed where sweat glands are most numerous on the palms of the hands, soles of the feet and forehead. Large area nickel electrodes are used alternatively as an anode or a cathode and a direct current (DC) incremental voltage 4 volts is applied on the anode. This DC iontophoresis induces a voltage on the cathode and generates a current. The intensity of about 0.2 mA are obtained between the anode and the cathode, related to chloride concentration. The electrochemical phenomena are measured by two active electrodes (the anode and the cathode) successively in the three regions, while the four other passive electrodes allow retrieval of the body potential.

[3] Mothiram K Patila, Vasanth Bhat M, Mahesh M. Bhati; Parivalavan R, Narayanamurthy V. B. Andganesan V. Snov - New Methods and Parameters for Dynamic Foot Pressureanalysis in Diabetic Neuropathy.

Walking foot pressures are found to be affected by the weight of the person and their walking velocity. It is also found that both the magnitude and duration of the dynamic foot pressures are important in the formation of ulcer in neuropathic feet of diabetic patients. Therefore, foot pressure measurements are made on a long optical pedobarograph which could accommodate at least two steps. The foot pressure analysis is done using two new parameters: Normalized Peak Pressure, NPP and Pressure Contact Ratio, PCR, which take into consideration the weight of the person. Walking velocity and magnitude and duration of the peak foot pressure acting in ten areas of the foot

[4] C. Lebosse, B. Bayle, M. de Mathelin IlIkirch, P. Renaud LGeCo, INSA-Strasbourg, - Nonlinear Modeling of Low Cost Force Sensors.

In this paper, nonlinear modeling of low cost force sensors is considered for force control applications in robotic or biomechanical applications. Commercial force sensors are often expensive, with a limited use in severe conditions such as the presence of a strong magnetic field. On the contrary, thin film piezoresistive sensors such as the Tekscan Flexiforce and the Interlink FSR sensors are of low cost and can be considered in such an environment. Only a few information is however available on their dynamic properties. We therefore provide an experimental study of their dynamic behavior, showing nonlinear properties. Identification is then achieved, and a compensation model is proposed. A force control experiment is finally presented to evaluate the compensation scheme. The traditional orthotic insole by taking ink impression is not sufficient to correct the orthotic problems like misalignments and stability. Foot orthosis is used to alter foot biomechanics and associated dysfunction.

[5] Sikyung Kim, Mohammad M. G. Mazumdc, - A Last Design with Uniform Foot Pressure Free Form Deformation.

The human foot has different shapes according to sex and age. It is an essential factor to consider the individual foot shape and characteristics. The conventional last design method does not take care of these factors and it just depended on the method based on bare eyes and skillful hands. Those results in the last design are not proper for the human foot. To solve these problems, the last end shoe has to be designed based on the 3dimension (3d) foot shape and foot pressure data. This paper presents a 3d last design system utilizing a Uniform Foot Pressure Free Form Deformation (UFPFFD). The proposed UFPFFD is operated on the rule of foot pressure unbalance analysis and FFD. The deformation factor of the UFPFFD is constructed on the FFD lattice with the foot pressure unbalance analysis on the measured 3d foot shape. Planter foot pressure studies, in patients with diabetic neuropathy indicated relationship between excessive pressure and ulceration.

[6] Mothiram K Patila, Vasanth Bhat, Mahesh M. Bhati, Parivalavan R, Narayanamurthy V. B. and Ganesan V. S, - New Methods and Parameters for Dynamic Foot Pressure Analysis in Diabetic Neuropathy.

Walking foot pressures are found to be affected by the weight of the person and walking velocity. It is found that both the magnitude and duration of the dynamic foot pressures are important in ulcer formation in neuropathic feet. This paper describes a method of using new parameters: Normalized Peak Pressure (NPP), and Pressure Contact Ratio (PCR) to understand pressure distribution patterns under the soles of diabetic subjects with neuropathic feet possibly responsible for ulcer formation. The measurement of dynamic foot pressure, on normal as well as 3 classes of diabetic subjects, is carried out using optical pedobarograph. The foot is divided into ten areas and they are scanned to find maximum values of the new parameters in each of these areas. A statistical study of the foot pressure parameters for normal and three classes of diabetic patients indicate distinguishing trends and hence could possibly provide a quantitative insight into the condition of the foot to the clinician and may aid in better diagnosis and therapy planning. Appropriate color intensities are used to indicate different pressure distribution of foot.

[7] DV Rai, LM Aggarwal, Raj Bahadurl - Plantar Pressure Changes in normal and Pathological Foot during bipedal standing

An attempt has been to study the pedographs of left and right in normal and pathological subjects during bipedal standing. Percentage pressure profiles were plotted to see the distribution of loading on the plantar surface of the foot. Plantar pressure measurement techniques are useful in the analysis and understanding of the biomechanics of human foot. It was found that orthotics attenuated the peak pressure and distributed it uniformly on the plantar area of the foot. The data seem to be useful in understanding the biomechanics of bipedal standing.

[8] A.N. Nithya, R. Premkumar, S. Dhivya, M. Vennila - A Real Time Foot Pressure Measurement for Early Detection of Ulcer Formation in Diabetic Patient Using Labview.

The threshold is set in the voltage form and used for the diagnosis of foot ulcer. Here the input is taken from 6 regions. So accuracy of that is less. In order to improve the accuracy level of the signal, foot regions are taken into account can be increased by 10 for each leg. This paper presents the results of the study undertaken on 10 feet of normal and 4 feet of diabetic subjects, to find the relationship between the foot pressures characterized by the parameter known as NPP at different levels of pressure responsible for causing foot ulcer

9] Mahesh M. Bhatia, MS and K.M. Patil, DSc - New On-line Parameters for Analysis of Dynamic Foot Pressures in Neuropathic Feet of Hansen's Disease Subjects

Pressures on the foot during walking are affected by the weight of the person and the walking velocity. It is also found that both the magnitude and duration of the dynamic foot pressures are important in ulcer formation in the neuropathic feet of persons with Hansen's disease (HD). Therefore, new parameters, Normalized Peak Pressure (NPP) and Pressure Contact Ratio (PCR), are calculated from dynamic foot pressure data in 10 defined areas of the feet of 52 non-impaired controls and 108 persons with HD with different pathologies, using a long barograph that could accommodate at least two foot prints in one walking cycle. Statistical study of these new parameters, for various classes of HD subjects, shows significantly different mean values in the foot areas and hence could aid the clinician in better diagnosis and therapy planning. The second part of the article deals with on-line calculations and gray scale display of these parameter transforms for all the points on the plantar surfaces of both feet in a way that could help the clinician in quick analysis and better management and care of neuropathic feet.

[10] S. L. Patil, Madhuri A. Thatte, U. M. Chaskar - Development of Planter Foot Pressure Distribution System Using Flexi Force Sensors

Quantitative Planter foot pressure measurement system using tlexi force sensors is developed. This system can be used to measure pressures at heel, MTI, MT2 and toe. The result shows the comparisons of the planter foot pressure distribution behavior between normal subject and diabetic patients. Diabetic patients have higher pressures at their metatarsal heads compared to normal subjects. This system can aid in deciding suitable foot wear for diabetic patients. The planter pressure values of normal subject selected areas lie between 50 to 400 KPa. It is envisaged that the said technique, developed and tested is effective biomechanical tool to diagnose various disorders related to foot.

Chapter 3

FOOT ULCER DETECTION SYSTEM FOR DIABETIC PATIENTS

3.1 Scope and Objectives

Healthcare and wellness management for the diabetic is one of the most promising information technology in the field of medical science. A health care monitoring system is necessary to constantly monitor diabetic patients' physiological parameters. The smart medical system focuses on the measurement and evaluation of vital parameters e.g. SPO2, electrocardiogram (ECG), heart rate variability, foot ulcer detection etc.

The major objectives of the system include:

- To present a smart health monitoring system that has the capability to detect the specific abnormality of Respiratory function that indicates the situations known as Pulmonary Edema.
- To develop a system that can analyses the signal periodically and detect the normal or abnormal conditions to detect Pulmonary Edema that results to Renal failure in diabetic patients.
- Also to develop a smart system that can detect the Diabetic Foot Ulcer(DFU) that helps to reduce the bacterial load on the foot.

Hence the major scope of this proposed project work is to develop a Smart health monitoring system that overcomes many complications in diabetic patients by periodically monitoring patients heart beat rate, SPO2(Peripheral capillary oxygen saturation) level, foot pressures etc. Therefore, IOT concept is used and sensors are connected to human body with well managed wireless network which periodically monitors the physiological parameters of the body to avoid high risks in diabetic patients. Continuous health monitoring remotely works because of integration of all components with wearable sensors and implantable body sensors networks that will increase detection of emergency conditions at risk. Also the proposed system is useful to operate remotely because of in built Wi-Fi in the system.

Hence a new secure IOT Based Modern Healthcare monitoring system for diabetic patients is proposed, to give flexibility and fast operational speed to get expected outcomes. In this hardware, elements used are Arduino Mega 2560, pulse oximeter and heart rate sensor, pressure sensors etc. More sensors also can be used to detect various biological functionalities. The proposed Smart system comprises of four main parts. The first part being detection of blood oxygen level to recognize the indication of pulmonary edema, second being detection of heartbeat to indicate the cardiac arrest, the third part is to detect the pressure from the pressure sensors to detect the foot ulcers under normal or abnormal conditions of patients and the last part is to provide the detected data for remote viewing. Remote viewing of the data enables a doctor or health specialist to monitor a patient’s health progress away from hospital premises in any emergency and non-emergency conditions

3.2 Implementation

The components used in this proposed model include Arduino MEGA 2560, a power supply unit, pressure sensors, a LCD display, GSM Module, Pulse oximeter and heart rate sensor. The Arduino MEGA 2560 is used as a central processing unit for monitoring the heart rate, SPO2 and foot ulcer of the patients. The working of this project is explained with the help of a block diagram shown in the Fig.3.1.

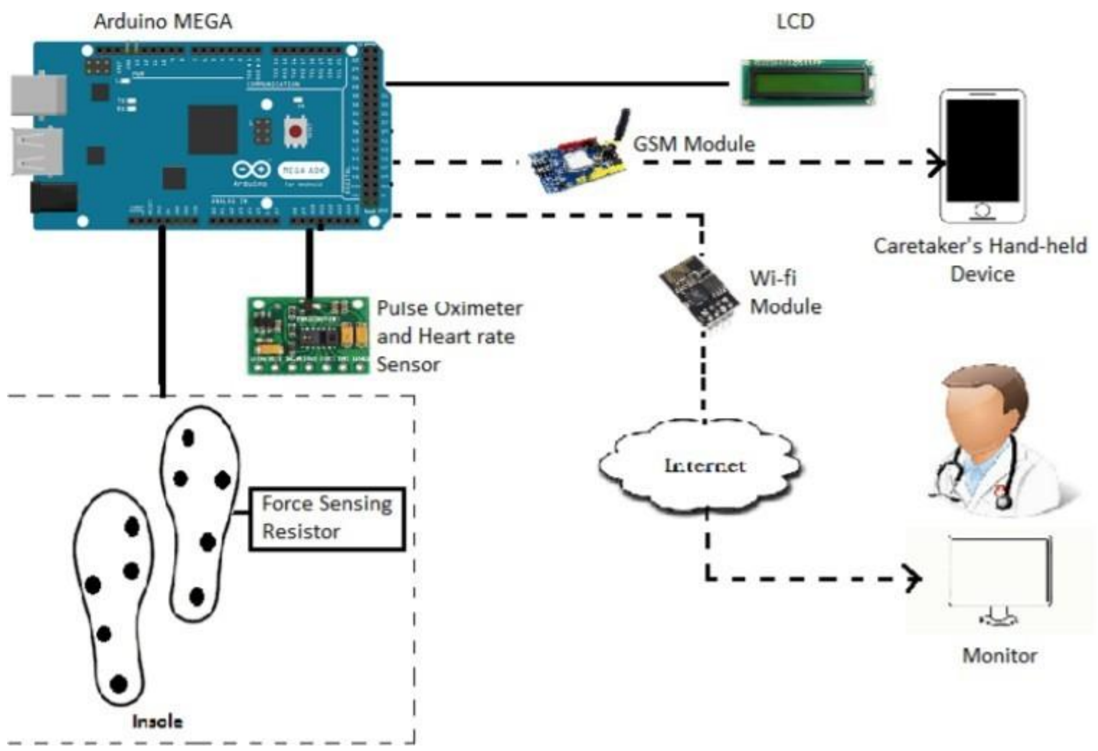


Fig 3.1 Implementation

There are two main sections: Transmitter section and the Receiver Section

The transmitter section comprises an insole which consists of pressure sensors• known as Force Sensing Resistor sensors placed on the 5 areas of rubber insole to detect the pressure at various areas of each foot [4]. Continuously the data is sent to the Arduino MEGA 2560. The Pulse oximeter and heart rate sensor collects data when the patient places a finger on it and it detects the blood oxygen saturation level and Heart rate of a diabetic patient. The transmitted data is encoded in to serial data over the air through RF module i.e. GSM and Wi-Fi module and subsequently the measured values of the patients are displayed on the LCD display and in case of emergency an SMS alert is send to patients or caretakers mobile. With the help of an antenna placed at the transmitter end, the data is transmitted to the receiver section.

- The receiver section is RPM (Remote Patient Monitoring) system which is a technology used for monitoring patients outside of conventional clinical settings. For example, in the home settings or hospitals which may lead to increase in the care of patient and decrease in the healthcare delivery cost. The remote healthcare system offers Healthcare specialists and doctors to access the digital data of HR, SPO2 and foot pressure sensors' output to a centralized view of all the diabetic patients allowing clinicians to tailor workflows, protocols and interventions, creating customized care plans according to a patient's condition and status and hence alerts and reminders that trigger patient in case of medical emergencies. Measured Data coming from sensors to Arduino MEGA 2560 is processed to convert it to digital format that makes it easy to process data in system digital format so that it gives advantage on operational speed. Digital processing is much more efficient than analogue signal. Database used is Things board platform. We use this platform because data can be stored and viewed as a table and in different widgets as required, it is also easy and flexible to use. Data coming from sensors to Arduino MEGA 2560 is compared with the defined thresholds. When abnormal data is indicated, alert message will be sent to doctor's and caretakers' mobile so that it can avoid risk and handle critical situation.

3.3 Block Diagram

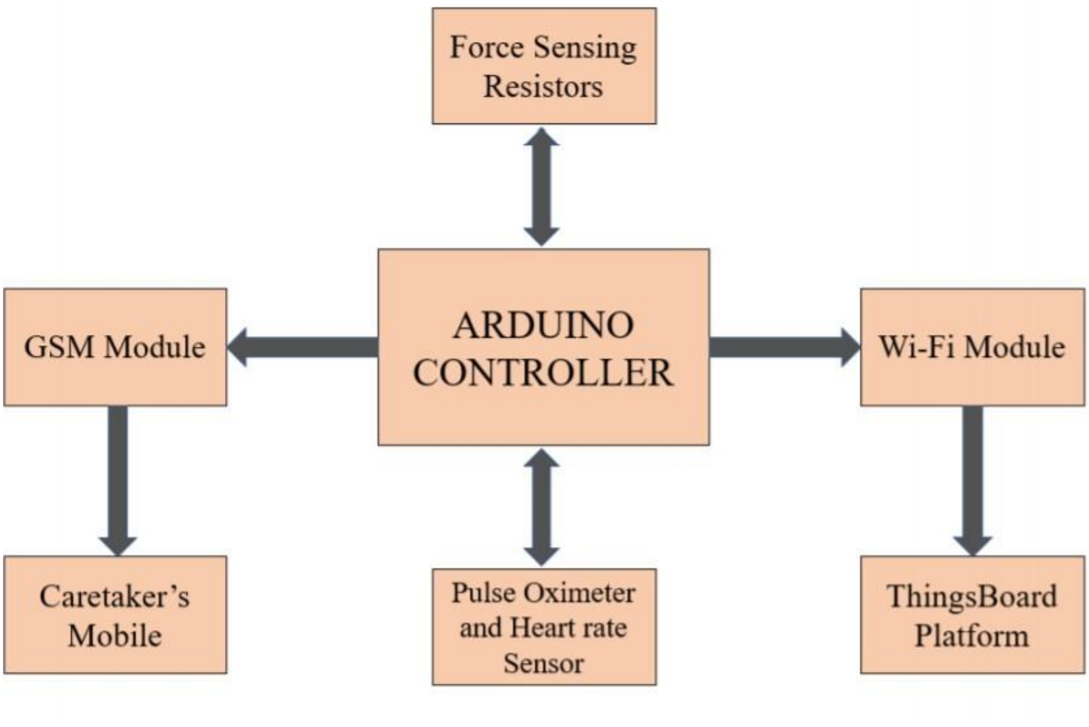


Fig 3.2 Block Diagram

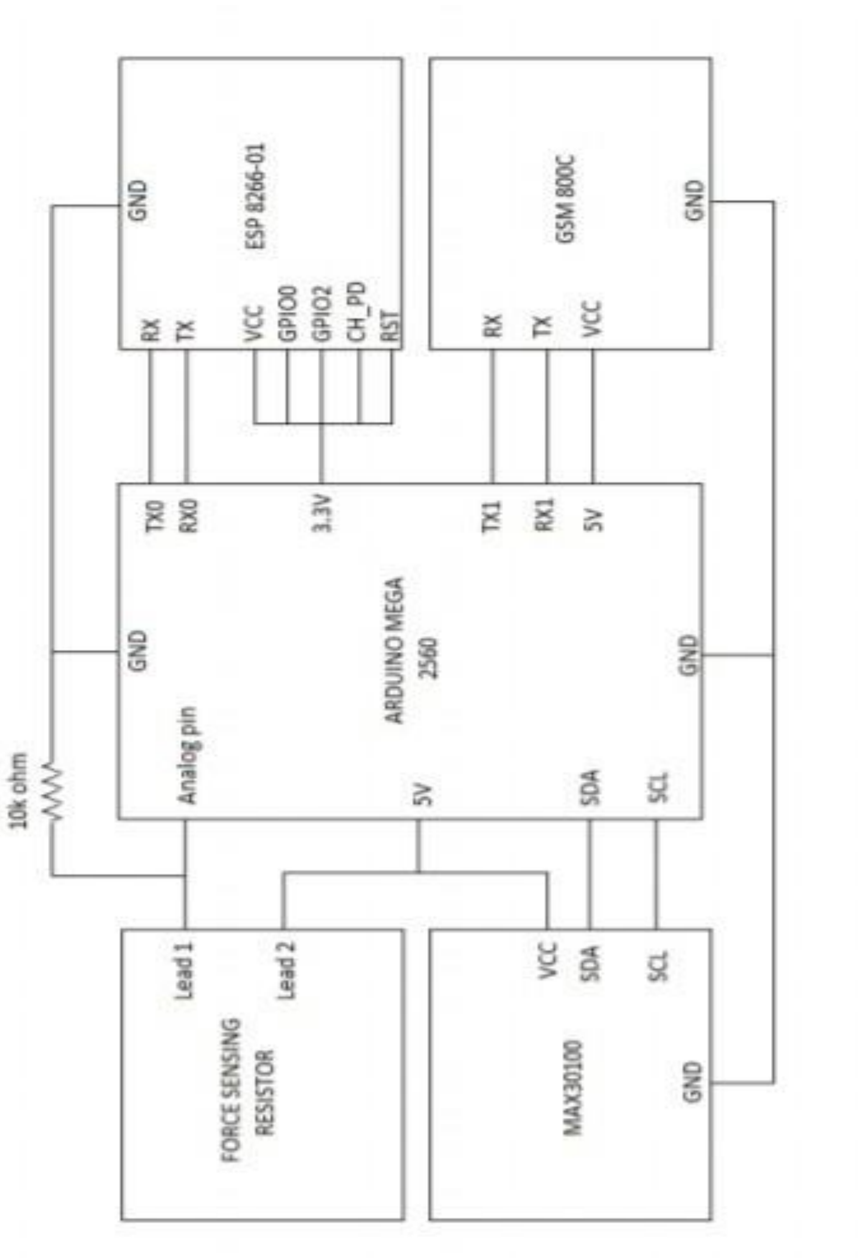


Fig 3.3 Pin Diagram

3.4 Working

1. The connections are made as shown in the pin diagram.

2. There are two functions to be performed, one is calculating the foot pressures and the other being measurement of heart rate and SpO2.

3. The keypad allows us to select one function at a time from the available two functions.

4. When key one is pressed, Foot pressure measurement is triggered and when key two is pressed MAX30100 is triggered.

5. Data is acquired from FSR sensors and MAX30100 by the Arduino controller.

6. The data is processed in the Arduino controller and compared with the specified thresholds.

7. The Arduino is connected to the GSM module, that is used to send alert messages to the caretakers' or patient's phone.

8. The Wi-Fi module is an intermediate between Arduino and cloud.

9. Things board's dashboard is operated through Wi-Fi.

10. The data stored in Things board can be viewed by the doctor from anywhere.

11. The link to the dashboard can be privately shared to monitor the data.

12. The same data is also available on the LCD for immediate view.

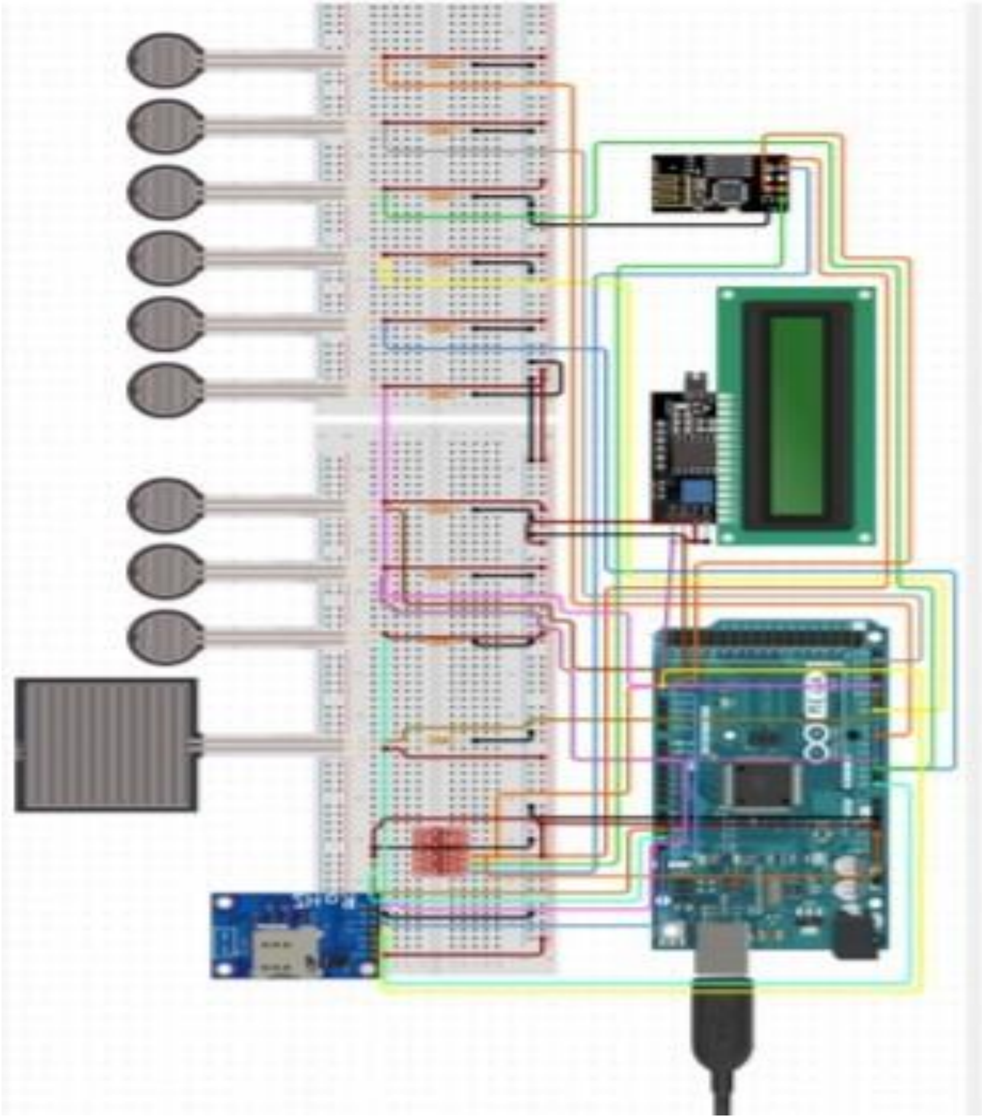


Fig 3.4 Components Connected

3.5 Flow Chart

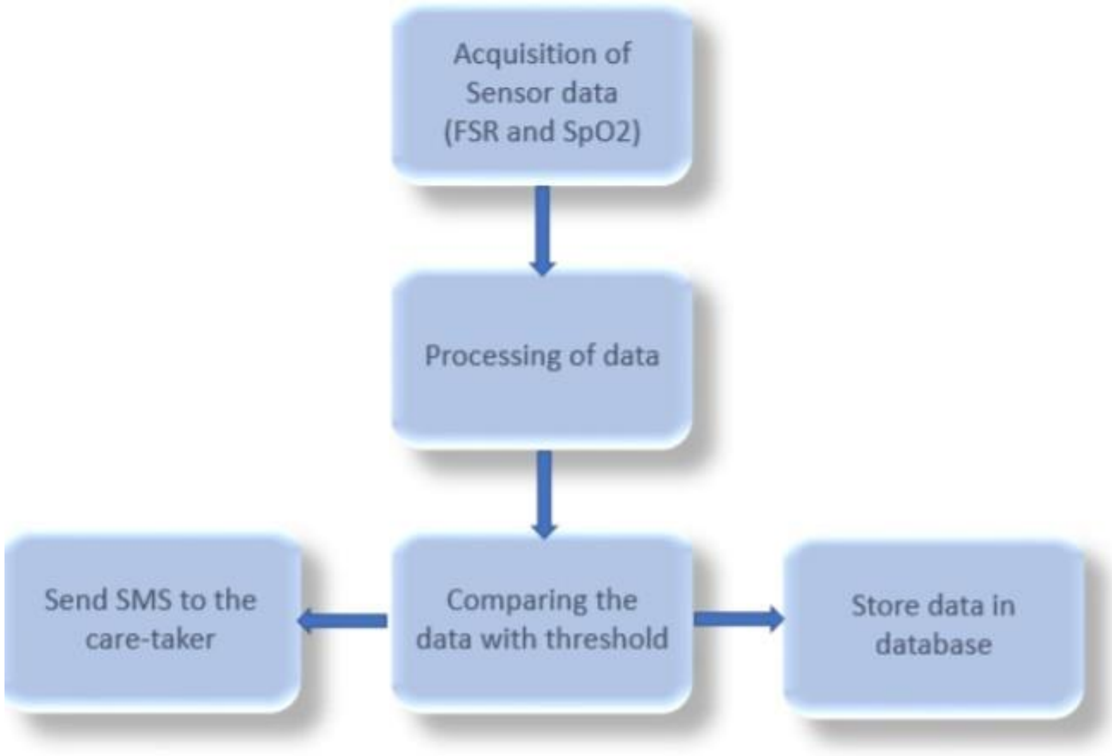


Fig 3.5 Flow Chart

3.6 Hardware Components

3.6.1 Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Power:

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm Centre-positive plug into the board's power jack. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

● **VIN:**

The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

● **5V:**

The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply

● **3V3:**

A 3.3-volt supply generated by the on-board regulator. Maximum current drawn is 50 mA.

● **GND**: Ground pins.

Memory The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM

● **Input and Output:**

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50k Ohms. The Mega2560 has 16 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default, they measure from ground to 5 volts.

In addition, some pins have specialized functions:

● **Serial**: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB to TTL Serial chip.

● **I2C:** 20 (SDA) and 21 (SCL). Support I2C (TWI) communication using the Wire library. SCL is the clock line. SDA is the data line.

● **Reset:** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware

UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer.

Programming

The Arduino Mega can be programmed with the Arduino software.

Fig 3.6 Arduino Mega 2560

3.6.2 Force Sensing Resistors

A force-sensing resistor is a material whose resistance changes when a force, pressure or mechanical stress is applied. They are also known as "force-sensitive resistor" and are sometimes referred as "FSR".

Force-sensing resistors consist of a conductive polymer, which changes resistance in a predictable manner following application of force to its surface [5]. They are normally supplied as a polymer sheet or ink that can be applied by screen printing. The sensing film consists of both electrically conducting and non-conducting particles suspended in matrix. The particles are sub-micrometer sizes, and are formulated to reduce the temperature dependence, improve mechanical properties and increase surface durability. Applying a force to the surface of the sensing film causes particles to touch the conducting electrodes, changing the resistance of the film. As with all resistive based sensors, force-sensing resistors require a relatively simple interface and can operate satisfactorily in moderately hostile environments. Compared to other force sensors, the advantages of FSRs are their size (thickness typically less than 0.5 mm), low cost and good shock resistance. A disadvantage is their low precision: measurement results may differ 10% and more. Force sensing capacitors offer superior sensitivity and long term stability, but require more complicated drive electronics.

Most FSR's feature either a circular or rectangular sensing area. The square FSR is good for broad-area sensing, while the smaller circular sensors can provide more precision to the location being sensed.

Resistor is one of the most typically used passive components in electrical and electronics circuits. Resistor can be defined as a circuit element used for reducing current flow and also lower voltage levels in circuits. There are different types of resistors classified based on various criteria such as fixed value resistors, variable resistors, wire wound resistors, metal film resistors and special resistors. The special purpose resistors can be listed as pencil resistors, light dependent resistors, force sensing resistors and so on

Force sensing resistor can be defined as a special type of resistor whose resistance can be varied by varying the force or pressure applied to it. The FSR sensor technology was invented & patented by Franklin Event off in 1977. The FSR sensors are made of conductive polymer which has a property of changing its resistance based on the force applied to its surface. Hence, these are termed as FSR sensors, force sensing resistor is a combination of resistor and sensor technology.

Specifications:

- Length: approx. 60mm/2.36"
- Width: approx. 19mm/0.75"
- Sensing area: 12.7mm/0.5"
- Output signal: Passive variable resistance
- Force sensing range: 0g~10kg

Fig 3.7 FSR (round and square)

3.6.3 MAX30100

Pulse oximetry is a non-invasive method for monitoring a person's oxygen saturation (SO2).

In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. The device passes two wavelengths of light through the body part to a photo detector. It measures the changing absorbance at each of the wavelengths, allowing it to determine the absorbance due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish.

A blood-oxygen monitor displays the percentage of blood that is loaded with oxygen. More specifically, it measures what percentage of haemoglobin, the protein in blood that carries oxygen, is loaded. Acceptable normal ranges for patients without pulmonary pathology are from 95 to 99 percent.

A typical pulse oximeter uses an electronic processor and a pair of small light-emitting diodes (LEDs) facing a photodiode through a translucent part of the patient's body, usually a fingertip or an earlobe. One LED is red, with wavelength of 660 nm, and the other is infrared with a wavelength of 940 nm. Absorption of light at these wavelengths differs significantly between blood loaded with oxygen and blood lacking oxygen. Oxygenated haemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated haemoglobin allows more infrared light to pass through and absorbs more red light. The LEDs sequence through their cycle of one on, then the other, then both off about thirty times per second which allows the photodiode to respond to the red and infrared light separately and also adjust for the ambient light baseline.

The amount of light that is transmitted (in other words that is not absorbed) is measured, and separate normalized signals are produced for each wavelength. These signals fluctuate in time because the amount of arterial blood that is present increases (literally pulses) with each heartbeat. By subtracting the minimum transmitted light from the transmitted light in each wavelength, the effects of other tissues are corrected for, generating a continuous signal for pulsatile arterial blood. The ratio of the red light measurement to the infrared light measurement is then calculated by the processor (which represents the ratio of oxygenated haemoglobin to deoxygenated haemoglobin), and this ratio is then converted to SpO2 by the processor via a lookup table based on the Beer–Lambert law.

Pulse oximetry is particularly convenient for non-invasive continuous measurement of blood oxygen saturation. In contrast, blood gas levels must otherwise be determined in a laboratory on a drawn blood sample. Pulse oximetry is useful in any setting where a patient's oxygenation is unstable, including intensive care, operating, recovery, emergency and hospital ward settings, pilots in unpressurized aircraft, for assessment of any patient's oxygenation, and determining the effectiveness of or need for supplemental oxygen.

Fig 3.8 MAX30100

3.6.4 ESP 8266-01

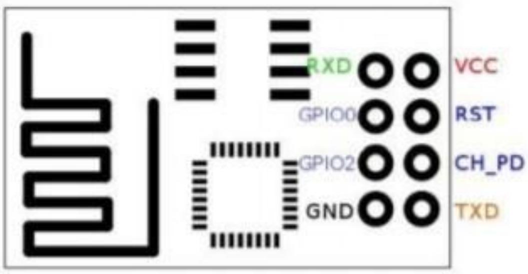
ESP8266 is a system-on-chip (SoC) which integrates a 32-bit Tensilica microcontroller, standard digital peripheral interfaces, antenna switches, RF balun, power amplifier, low noise receive amplifier, filters and power management modules into a small package. It provides capabilities for 2.4 GHz Wi-Fi (802.11 b/g/n, supporting WPA/WPA2), general-purpose input/output (16 GPIO), Inter-Integrated Circuit (I^2C), analog-to-digital conversion (10-bit ADC), Serial Peripheral Interface (SPI), I^2S interfaces with DMA (sharing pins with GPIO), UART (on dedicated pins, plus a transmit-only UART can be enabled on GPIO2), and pulse-width modulation (PWM). The processor core, called "L106" by Espressif, is based on Tensilica's Diamond Standard 106Micro 32- bit processor controller core and runs at 80 MHz (or overclocked to 160 MHz). It has a 64 KiB boot ROM, 32 KiB instruction RAM, and 80 KiB user data RAM. (Also, 32 KiB instruction cache RAM and 16 KiB ETS system data RAM.) External flash memory can be accessed through SPI. The silicon chip itself is housed within a 5 mm × 5 mm Quad Flat No-Leads package with 33 connection pads — 8 pads along each side and one large thermal/ground pad in the center.

ESP8266-01 is an impressive, low cost Wi-Fi module suitable for adding Wi-Fi functionality to an existing microcontroller project via UART serial connection. The module can even be reprogrammed to act as a standalone Wi-Fi connected device-just add power. The feature list is impressive and includes: 802.11 b/g/n protocol Wi-Fi Direct (P2P), soft-AP, integrated TCP/IP protocol stack. It is a self-contained SOC with integrated TCP/IP. This module is compatible for mobile devices, wearable electronics and networking applications. This device is ultra-low energy consuming device. It has three modes: active mode, sleep mode and deep sleep mode. The ESP8266 has 1 MB of built-in flash, allowing single-chip devices capable of connecting to Wi-Fi.

Fig 3.9 ESP 8266 -01

Specifications:

- 802.11 b / g / n
- Wi-Fi Direct (P2P), soft-AP
- Built-in TCP / IP protocol stack
- Built-in TR switch, balun, LNA, power amplifier and matching network
- Built-in PLL, voltage regulator and power management components
- 802.11b mode + 19.5dBm output power
- Built-in temperature sensor
- Support antenna diversity
- off leakage current is less than 10uA
- Built-in low-power 32-bit CPU: can double as an application processor



Label	Signal
VCC	3.3V (3.6V max) supply voltage
GND	Ground
TXD	Transmit Data (3.3V level)
RXD	Receive Data (3.3V level!)
CH_PD	Chip Power down: (LOW = power down active)
GPIO0	General Purpose I / O 0
GPIO2	General Purpose I / O 2
RST	Reset (reset = LOW active)

Fig 3.10 Pin specifications of ESP 8266-01

3.6.5 GSM SIM 800C

GSM is a mobile communication modem; it stands for Global System for Mobile communication (GSM). A GSM digitizes and reduces the data, then sends it down through a channel with two different streams of client data, each in its own particular time slot.

SIM 800C Module is a complete Quad-band GSM/GPRS solution in a SMT type, which can be embedded in the customer applications. These modules are sub-system of the Internet-of-everything hardware. SIM800C supports Quad-band 850/900/1800/1900MHz, it can transmit Voice, SMS and data information with low power consumption. With tiny size of 17.6*15.7*2.3mm, it can smoothly fit into slim and compact demands of customer design.

Specification of SIM 800C Module

- Quad-band 850/900/1800/1900MH
- GPRS multi-slot class 12/10
- GPRS mobile station class B
- Compliant to GSM phase 2/2+
- Class 4 (2 W @ 850/900MHz)
- Class 1 (1 W @ 1800/1900MHz)
- Dimensions: 17.6*15.7*2.3mm
- Weight: 1.3g
- Control via AT commands
- Supply voltage range 3.4 ~ 4.4V
- Low power consumption
- Operation temperature: -40℃ ~85℃

Fig 3.11 GSM sim 800C

Chapter 4

SOFTWARE

4.1 Software Components

4.1.1 Arduino IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, mac OS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino compatible boards, but also, with the help of 3rd party cores, other vendor development boards.

The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main () into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program Arduino to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

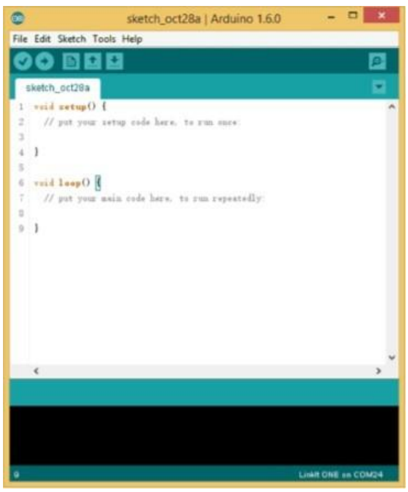


Fig 4.1 Arduino IDE

STEPS TO EXECUTE CODE USING ARDUINO

STEP 1

Arduino microcontrollers come in a variety of types. The most common is the Arduino UNO, but there are specialized variations. Before you begin building do a little research to figure out which version will be the most appropriate for your project

STEP 2

To begin, you'll need to install the Arduino Programmer aka the integrated development environment (IDE).

STEP 3

Connect your Arduino to the USB port of your computer. This may require a specific USB cable. Every Arduino us a different virtual serial-port address, so you need to reconfigure the port if you're using different Arduino.

STEP 4

Set the board type and the serial port in the Arduino Programmer.

STEP 5

Test the microcontroller by using one of the preloaded programs called sketches, in the Arduino Programmer. Open one of the example sketches, and press the upload button to load it. The Arduino should begin responding to the program: If you've set it to blink an LED light for example, the light should start blinking.

STEP 6

To upload new code to the Arduino, either you'll need to have access to the code you can paste into the programmer, or you'll have to write it yourself, using the Arduino programming language to create your own sketch. An Arduino sketch usually has five parts: a header describing the sketch and its author; a section defining variables; a setup routine that sets the initial conditions of variables and runs preliminary code; a loop routine, which is where you add the main code that will execute repeatedly until you stop running the sketch; and a section where you can list other functions that activate during the setup and loop routines. All sketches must include the setup and loop routines

STEP 7

Once you've uploaded the new sketch to your Arduino, disconnect it from your computer and integrate it into your project as directed.

4.2 Things board dashboard

Things Board is an open-source IOT platform for data collection, processing, visualization, and device management.

It enables device connectivity via industry standard IOT protocols - MQTT, COAP and HTTP and supports both cloud and on-premises deployments. Things Board combines scalability, fault-tolerance and performance so you will never lose your data.
Things Board features

- **Telemetry Data Collection**

Collect and store telemetry data in reliable way, surviving network and hardware failures. Access collected data using customizable web dashboards or server-side APIs.

- **Multi-tenancy**

Support multi-tenant installations out-of-the-box. Single tenant may have multiple tenant administrators and millions of devices and customers.

- **Data Visualization**

Provides 30+ configurable widgets out-of-the-box and ability to create your own widgets using built-in editor. Built-in line-charts, digital and analog gauges, maps and much more.

- **Horizontal scalability**

Amount of supported server-side requests and devices increase linearly as new things board servers are added in clustering mode. No downtime, server restarts or application errors.

- **IOT Rule Engine**

Process incoming device data with flexible rule chains based on entity attributes or message content. Forward data to external systems or trigger alarms using custom logic. Configure complex notification chains on alarms. Enrich server side functionality or manipulate your devices with highly customizable rules. Define your application logic with drag-n-drop rule chain designer.

- **Fault-tolerance**

All things board servers are identical. No master-workers or hot standby. Node failure is automatically detected. Failed nodes can be replaced without downtime. Persisted data is replicated using reliable NoSQL database.

- **Device Management**

Provides ability to register and manage devices. Allows to monitor client-side and provision server-side device attributes. Provides API for server-side applications to send RPC commands to devices and vice-versa.

- **Security**

Supports transport encryption for both MQTT and HTTP(s) protocols. Supports device authentication and device credentials management.

- **Asset Management**

Provides ability to register and manage assets. Allows to provision server side asset attributes and monitor related alarms. Ability to build hierarchy of entities using relations.

- **Customization and Integration**

Extend default platform functionality using customizable rule chains, widgets and transport implementations. In addition to MQTT, COAP and HTTP support, Things Board users can use their own transport implementations or customize behavior of existing protocols.

- **Alarms Management**

Provides ability to create and manage alarms related to your entities: devices, assets, customers, etc. Allows real-time alarms monitoring and alarms propagation to related entities hierarchy. Raise alarms on device disconnect or inactivity events.

- **100% Open-source**

Things Board is licensed under Apache License 2.0, so you can use any it in your commercial products for free. You can even host it as a SaaS or PaaS solution.

- **Micro services or Monolithic**

Supports monolithic deployment for getting started or small environments. Provides ability to upgrade to micro services for high availability and horizontal scalability.

- **SQL, NoSQL and Hybrid database**

Supports various database options and ability to choose where to store main entities and where to store telemetry data

Chapter 5

RESULTS

Foot pressure sensing platform system is developed using pressure sensors to early detection of foot ulcer caused by diabetic conditions. The result shows the comparisons of the pressure distribution on foot with different trials to detect the numbness and avoid the foot ulcers. This system can be used for finding the life threatening condition of deaths due to Pulmonary Edema and can be monitored to predict and alert in advance any indication of the body status.

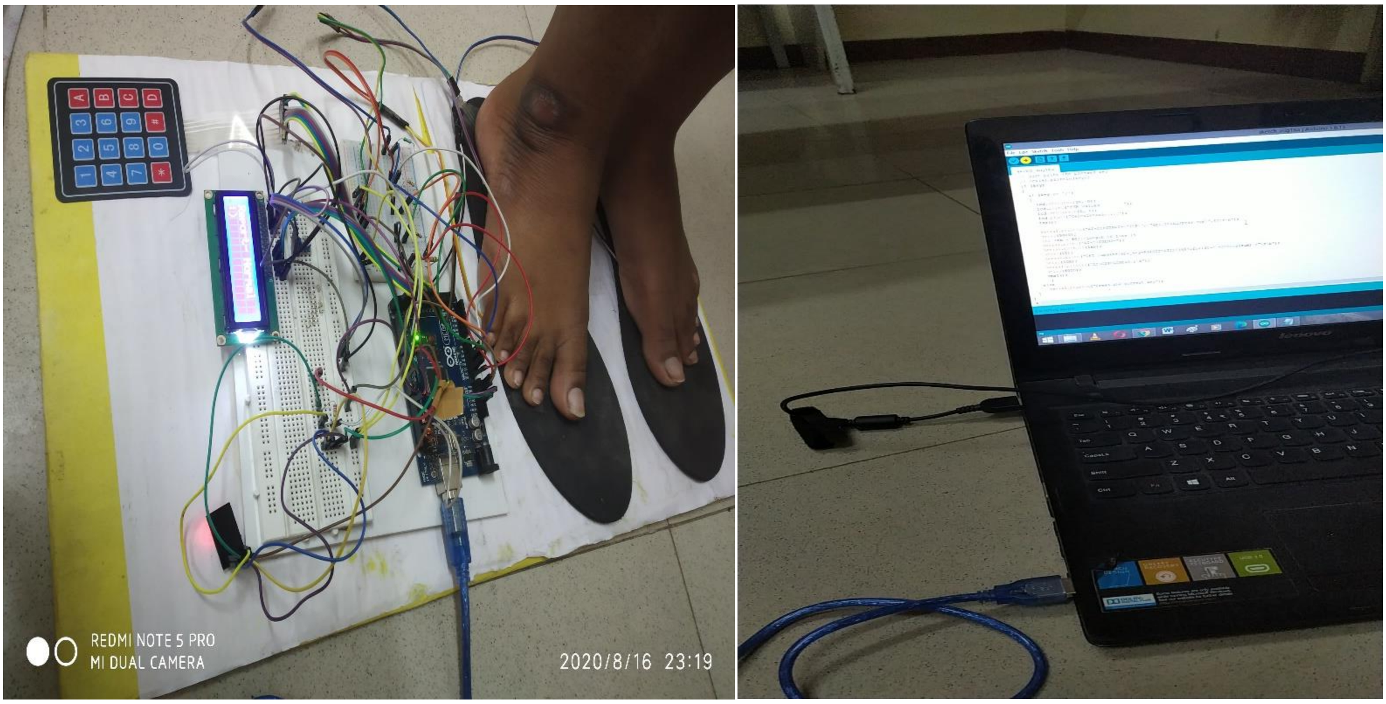


Fig 5.1 Complete setup

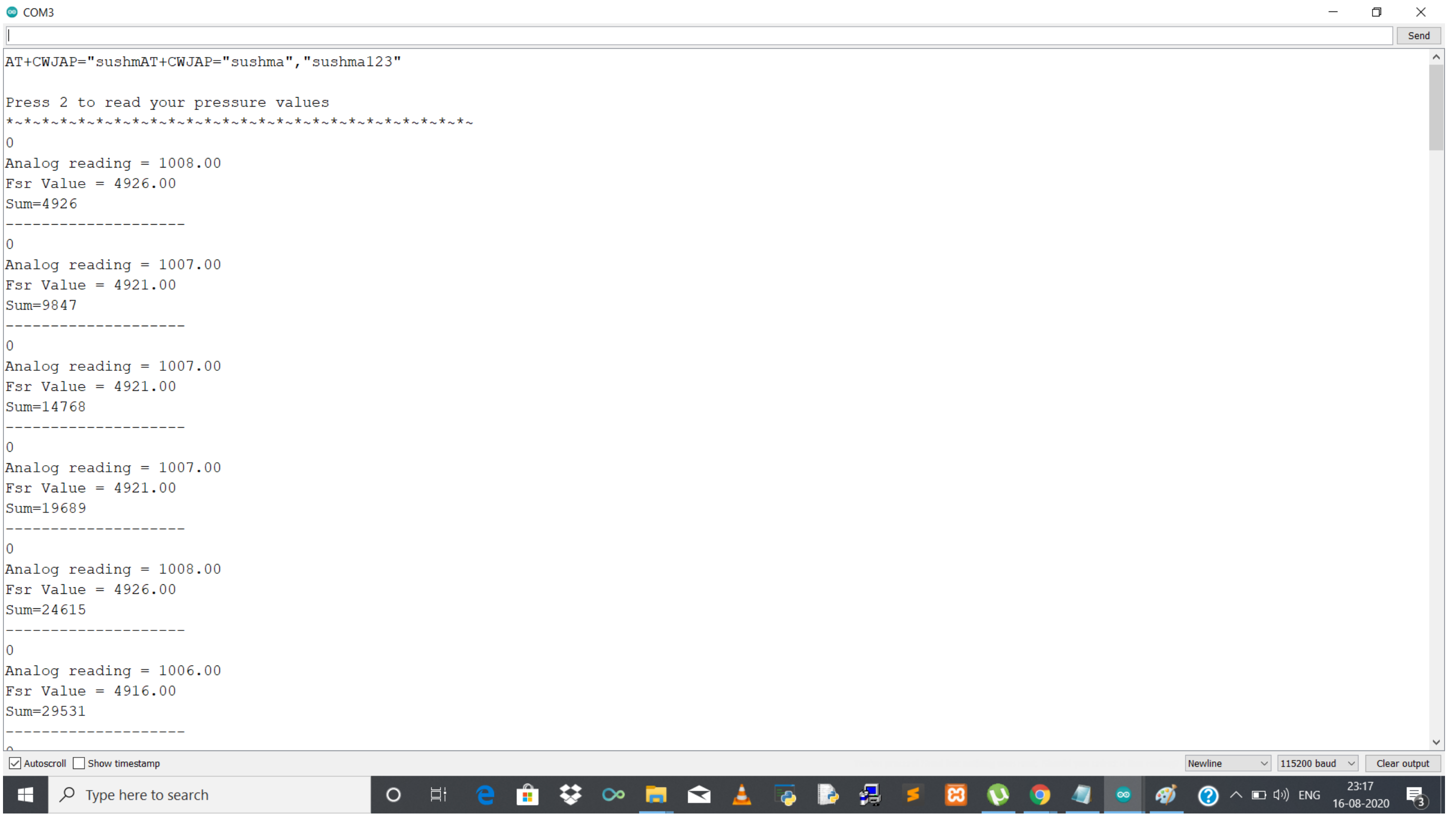
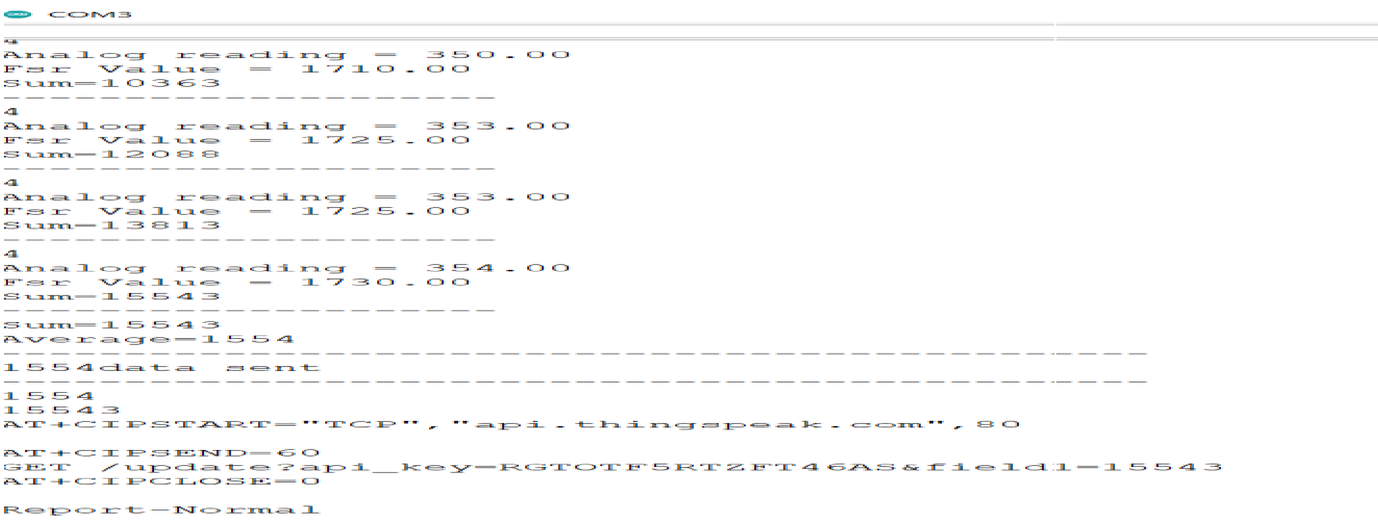


Fig 5.2 Results viewed on Serial Monitor



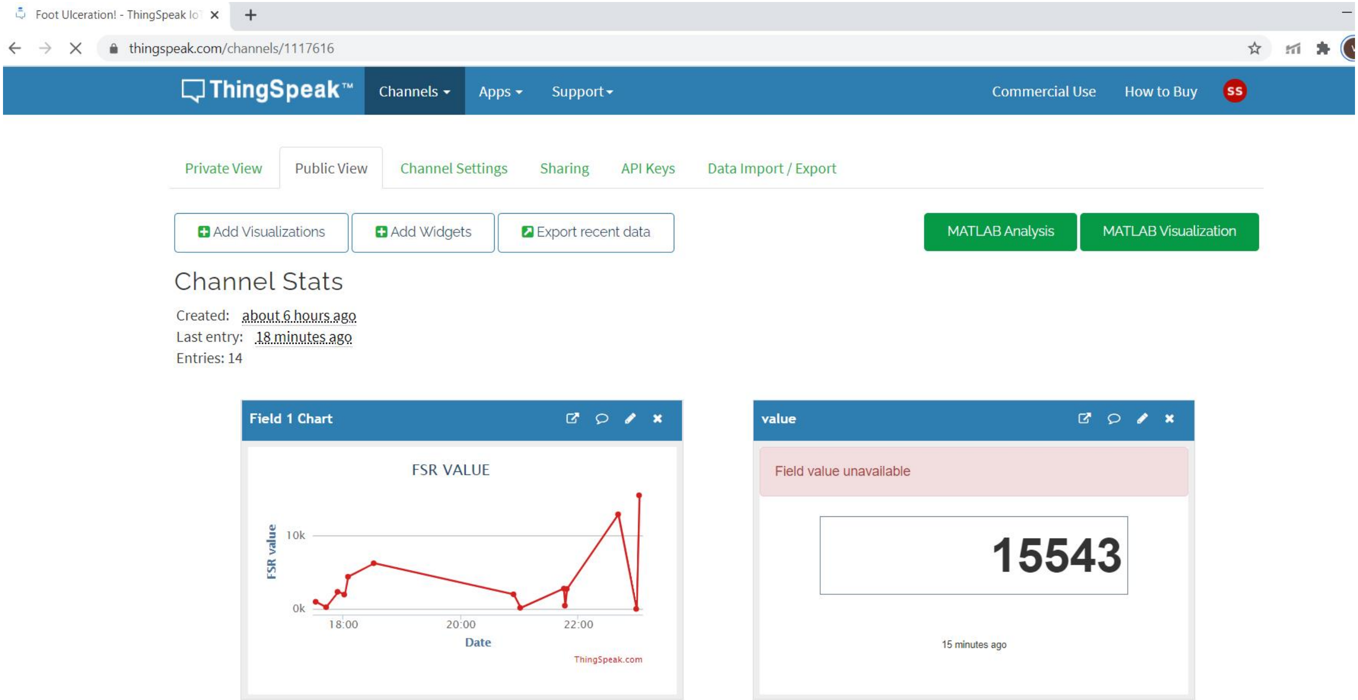


Fig 5.3 Results viewed on Thingspeak

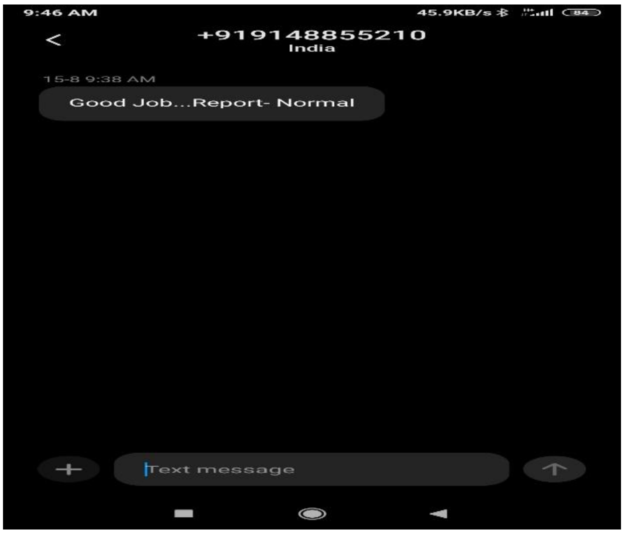


Fig 5.4 Results Viewed on Phone

In our project the threshold values are obtained for a person weighing between 50-60kgs. If the sensor values do not exceed the defined threshold values, the following result is obtained.

Chapter 6

APPLICATIONS AND ADVANTAGES

6.1 Applications

- The project is mainly used in chronic Health monitoring for all the types of diabetic patients. This project improves the initiative aimed to assist community health centers at both rural and urban areas of the city in redesigning their systems to increase diabetic patient self-management through goal setting and patient activation.
- In-House smart diabetic health systems are provided, which can be built from the customized systems in a matter of minutes as per the user's requirements.
- The proposed system is very useful for recorded vital data analysis and reporting. This system has an intelligent component that allows user to generate reports on the fly.
- For example, users can generate reports that list all patients with diabetics. These reports can also be created and saved.

6.2 Advantages

- A diabetic patient prone to the situation leading to development of a risky life threatening condition of deaths due to Pulmonary Edema can be monitored to predict and alert in advance any indication of the body status.

- The diabetic Foot ulcer can be monitored in earlier stage and reduces any foot amputation possibilities in diabetic patients.

- Increased patient satisfaction and overall quality of care can be found with the use of Remote Health care monitoring. This is, because of closer interaction with health professionals, reduced anxiety and smooth handling of emergency situations.

- There is a significant reduction of hospitalizations as patients suffering from chronic diseases are on a Remote healthcare monitoring program, hospital admissions can be reduced greatly.

- The proposed Smart health monitoring system leads to increased healthcare team productivity, enabling more evidence-based care and more efficient diabetic patient care management.

- Enhanced collaboration by the remote health care programs have proven to help enhance collaboration between healthcare providers. Acute care discharge planning is enhanced using the remote health care management solution.

- The overall system is small in size and easily portable.

- It is a time efficient system as it can replace the traditional methods of detecting ulcer that takes more time.

- Cost efficient

.• The dashboard data can be viewed privately by the care-taker or the doctor even when they are nor around the patient.

- Periodic measurement of Heart rate and SpO2 helps in the overall monitoring of the heart and lungs.

- The system can be customized based on the patient’s foot.

Chapter 7

CONCLUSIONS AND SCOPE FOR FUTURE WORK

The proposed technique consists of a Keypad that is used to choose between the calculation of foot pressure values or Heart rate/SpO2 one at a time. Force Sensing Resistor (FSR) is used to measure the foot pressures at 10 different points. The MAX30100 is used to measure heart rate and SpO2. We use Arduino MEGA to obtain data from the above sensors. The data is processed in the Arduino and then sent to the patient's/care-taker's phone as an SMS using the GSM 800C Module. The processed data is also sent to Things board platform through ESP8266-01(Wi-Fi) Module. Things board is an open source IOT platform for the device management, collection, processing and visualization of data.

This system can aid in deciding suitable foot wear for diabetic patients and walking style for a given time based on the data read sensor and shown in the hand held device. It is envisioned that the said technique, developed and tested is an effective biomechanical system to diagnose various disorders related to foot. Remotely, data can be accessible using GSM and WI-FI module to resolve many of the medical problems. As a future scope more number of FSR's can be added to the system to increase accuracy. The system can further be developed to alert a nearby hospital in case of an emergency condition and an ambulance can be sent immediately to the patient's location A GPS module can be installed in the system to provide location data to the hospital

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