Chapter 1

Introduction

1.1 Background :

Diabetes, or diabetes mellitus, is a condition in which the body's blood glucose levels exceed the normal range. Diabetes is a condition in which the pancreas is unable to generate an adequate quantity of insulin or the insulin that is produced is not utilized effectively by the body. Insulin is a hormone that regulates the level of glucose in the bloodstream. Insulin is a peptide hormone that is primarily endocrine in nature. It is responsible for binding to the plasma membrane-bound receptor to the targeted cell, thereby facilitating the anabolic response [1]. ISLETS of Langerhans assist the hormone-producing cells of the pancreas in the production of insulin through the use of beta cells. Relative insulin deficiency is characterized by the inability to satisfy the body's insulin requirements, despite the fact that insulin production is not halted, while absolute insulin deficiency is characterized by minimal or no insulin production in the pancreas.

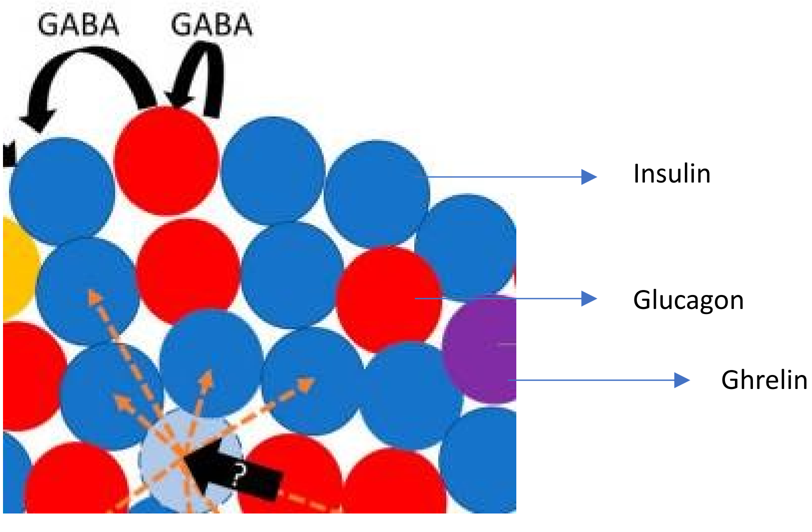


Fig 1.1: Interdependency of ISLETS cell [2].

Diabetes is a clinical condition characterized by hyperglycemia resulting from insufficient insulin production. Diabetes mellitus is defined by hyperglycemia resulting from both an absolute and relative deficiency in insulin production. Hyperglycemia leads to internal organ damage and various complications, including dysfunction of the retina, kidneys, nervous system, and feet. It is projected that there will be approximately 552 million individuals with diabetes mellitus by the year 2030 [3].

Diabetes mellitus can be classified into two subcategories: Type 1 and Type 2 diabetes mellitus.

Type-1: It leads to the destruction of pancreatic beta cells and induces autoimmune inflammation. This results in a complete insulin deficiency, characterized by an undetectable level of Peptide-C.

Type-2: This condition involves the complexity of a metabolic disorder characterized by beta cell dysfunction and varying degrees of insulin resistance. Insulin resistance is also observed in various health conditions such as obesity and hypertension.

Table 1.1: Diagnostic threshold of Diabetes mellitus [4]

Category	Fasting plasma glucose	2-hour plasma glucose	HbA_{1c}
Normal	< 6mmol/L	< 7.8 mmol/L	<3 9 mmol/L
Diabetes	≥ 7.0 mmol/L	≥ 11.1 mmol/L	≥ 48.1 mmol/L

HbA_{1c} is a testing procedure to calculate the average of blood sugar level for past two or three month from the day of performing this test.

Insulin governs the rate of fatty acid release from adipose tissue and the rate of fatty acid oxidation in muscle, while concurrently suppressing glucose use and oxidation; it also influences the concentrations of insulin-like growth factor I and II. The aforementioned parameters substantially affect the rate of glucose uptake by muscle [5]. External insulin infusion may substantially aid in the control of diabetes.

Dyslipidemia is characterized by abnormal blood lipid levels, either elevated or diminished compared to the normative range. Diabetic dyslipidemia (DD) is marked by elevated triglycerides and low-density lipoprotein (LDL) cholesterol, with a reduction in high-density lipoprotein (HDL) levels, both pre- and postprandially [5] which poses a significant risk for cardiovascular disease [6]. HDL has a strong correlation with long-term diabetes, although its correlation with early diabetes is weak [7]. Luo et al. (2014) propose that HDL is more strongly connected with Diabetes Mellitus-related Acute Ischemic Stroke (AIS) than with the mere presence of AIS, which exhibited a higher incidence value for LDL. This research indicated that age is a contributing factor, since it revealed a greater reduction in HDL levels among those aged 70 or younger [8].

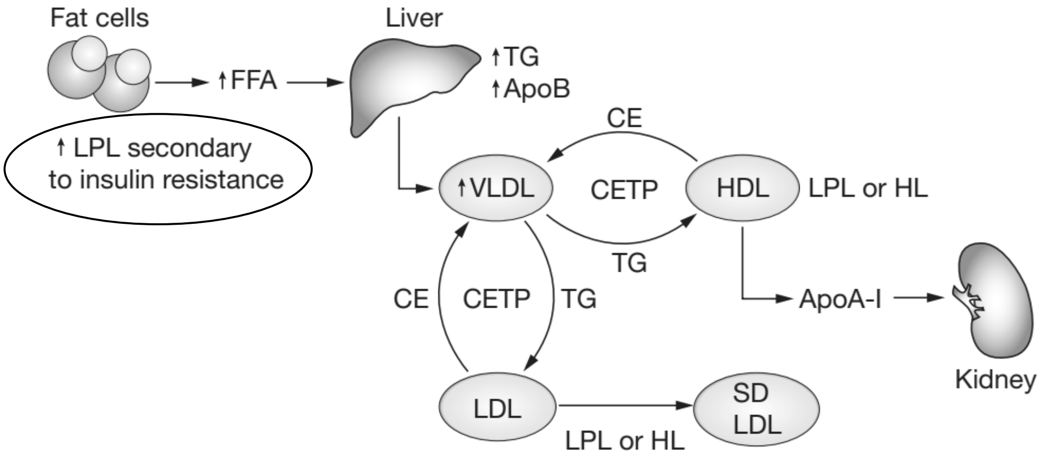


Fig 1.2: The function of insulin in diabetes mellitus. Insulin resistance initiates elevated triglycerides, reduced HDL, and increased HDL [6].

In this effort to develop a new diabetes monitoring and insulin infusion system, it is deemed essential to concurrently assess cholesterol and glucose levels.

Diabetic retinopathy (DR) is regarded as a visual problem resulting from diabetes mellitus. It is seen in type 1 and type 2 diabetes. Prolonged diabetes and unmanaged glucose levels have resulted in diabetic retinopathy, leading to visual loss. Sitti et al., 2016 indicated that a 2.5-year-old diabetic dog had no indications of diabetic retinopathy (DR), although after 5 years, it was diagnosed with severe DR [9].

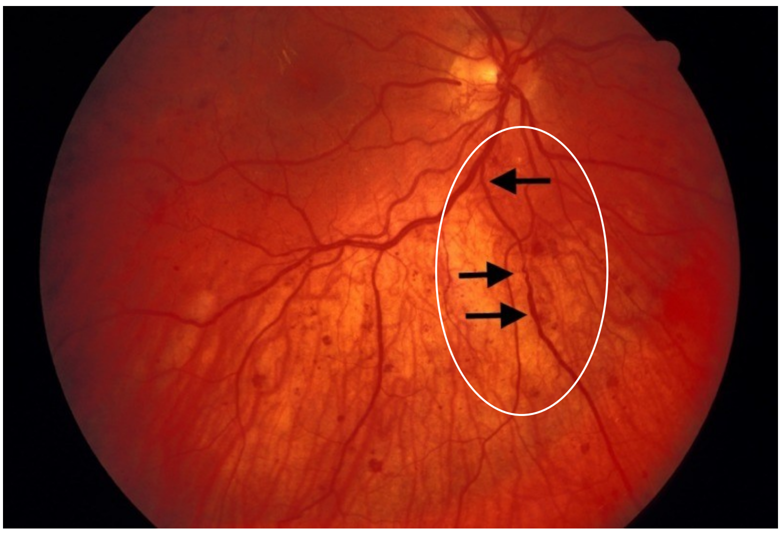


Fig 1.3: Proliferative Diabetes Retinopathy (courtesy: UCSF Department of Ophthalmology)

Diabetic Foot Ulcer (DFU) is a complication in the foot that results in wounds and sores. Fifteen percent of diabetic patients get diabetic foot ulcers (DFU), and twenty percent of hospital admissions for diabetes mellitus (DM) are associated with symptoms of DFU [10]. The risk factors for diabetic foot ulcers (DFU) include gender, a diabetes duration over 10 years, elevated body mass index (BMI), foot deformities, and increased plantar pressure, among others. Inadequate glucose regulation is seen as a primary contributor to diabetic foot ulcers (DFU) [11]. It might be said that an insulin infusion system is essential for the improvement of diabetic foot ulcers (DFU).

1.2 Motivation:

Diabetes mellitus is a burden for the afflicted. It requires consistent lifelong medication, a nutritious diet, regular consultations with physicians, and the management of glucose levels by the administration of insulin when they deviate from the usual range. These matters are very burdensome to manage in daily life. Given the hectic lifestyle of the contemporary world, it is very challenging for diabetes patients to manage all necessary aspects of their condition. It requires ongoing support to facilitate diabetes monitoring and provide essential notifications. We are in the era of the Fourth Industrial Revolution, characterized by automation and non-invasive measuring techniques. Diabetic patients need an application-based system to monitor their status, including glucose levels, cholesterol, heart rate, and SpO2, via a non-invasive measurement device shown on a web application. Administering the syringe is laborious, and the likelihood of forgetfulness or inaccessibility is prevalent in this context. This system must be fitted with a semi-automatic insulin infusion mechanism. The insulin infusion system must be regulated by both the human and automated mechanisms in accordance with glucose levels.

1.3 Our Approach:

This research project aims to develop a microcontroller-driven rack-and-pinion system for the administration of insulin into the patient's muscle to regulate glucose levels in the body. This gadget is designed for the continuous monitoring of heart rate (HR), oxygen saturation (SpO2), and non-invasive evaluation of glucose and cholesterol levels with a regression approach. The data is shown in the web application created using Flask, with patient-controlled insulin infusion syringe mechanisms. The online application has been coupled with an AI-based approach for identifying retinopathy and foot ulcers. The web-based application must have a method for monitoring diabetic medication consumption, a notification system, and a mechanism to manage past and upcoming doctor appointment deadlines.

Chapter 2

Literature Review

2.1 Literature Review:

Darbey et al. (2016) evaluated several nutritional mobile monitoring applications and shown their significant efficacy in aiding diabetes patients. The study indicated that diabetes patients using support applications have reduced levels of glycosylated hemoglobin compared to individuals who do not utilize such applications [12]. Rodriguez-Leon et al. (2021) examined several mobile and wearable devices for monitoring diabetes-related parameters and concluded that the accelerometer is the most often used sensor for detecting glucose and heart rate [13]. Grzybowski et al. (2020) studied many AI-based diabetic retinopathy diagnosis systems and found that several are commercially accessible, demonstrating good sensitivity and specificity with advanced deep learning algorithms [14]. Tulloch et al. examined 37 of 3,769 publications and shown that Neural Networks and Support Vector Machines (SVM) exhibit superior sensitivity and specificity [15]. Additionally, numerous studies are examined in this literature review that address the automated insulin infusion system. The work by Tuhong Zheng et.al [2], suggested a hardware framework that consists of NIR unit transmitter, receiver, and signal amplifier. NIR region was chosen because of its high S/N ratio and low absorbance in skin tissue and its non-destructive nature to the human skin cells. Arduino Uno is used as the CPU for data processing and LCD Display is used to display real time blood glucose values which is interfaced with the Arduino. Mobile application was developed to monitor the changes from time to time. Bluetooth module was also used to connect the Arduino and mobile application.

Although the device can measure blood glucose levels, the accuracy of the data can be enhanced by reducing the effect of the factors such a finger thickness and physiological variances.

The work carried out by I.M.M. Yusoff et.al [3] suggests that noninvasive detection of lipid molecules (lipoproteins) in blood can be used to predict cholesterol levels. The NIR spectrum was chosen because of its tight spacing, which reduces light interference inside the bloodstream. Given the different aspects of solute concentration in the blood, the absorbance property of lipid molecules is shown to be most efficient at around 1720nm. The photodiode used for NIR reception would be InGaAr, which has a high response for IR wavelengths.

The work by Anis SN [4], suggests that Glucose absorption is maximum at 940nm, and this wavelength is chosen for noninvasive measurement utilising NIR Spectroscopy. The light intensity is found to be related to the sample thickness and sample constituent content.

The work by P.Daarani et.al [5], suggests that light scattering occurs in biological tissues due to a mismatch between the refraction indices of cellular components. Hence blood glucose can be determined by measuring the intensity of NIR light 940nm after passing through the fingertip. Beer Lambert law gives the link between the absorbance of light through any solution. The length path travelled by the light ray is proportional to the concentration of the solution and the length path travelled by the light ray. The hardware system consists of an Atmel SAM3X8E microcontroller. The model predicts blood glucose value using regression analysis. Clarke Error Grid Analysis or Surveillance Error Grid Analysis can both be used to check the system's accuracy.

Ahniar et al.[6] proposed a non-invasive cholesterol measuring device using a photodiode sensor and a Blynk interface for real-time data monitoring and visualization. The error of measuring cholesterol in the blood using a module with a non-invasive method is 1.46%, with an accuracy of 98.54%.

Blank et.al [7], developed a system for measuring cholesterol and blood glucose levels in order to maintain track of patient health through a smart patient health tracking app. The sensors and microcontroller send out warning messages to the user via the mobile app when the system detects any abrupt changes in the patient's health state. Patient health tracking system using IoT successfully leverages wireless connection to monitor the patient's health in order to prevent emergencies.

Manurung et al. suggested a Non-Invasive Cholesterol Measuring Device Using a Photodiode Sensor With a BL YNK Interface. The model was built and trained on top of TensorFlow, and then converted for mobile use with the help of TensorFlow Lite, The model achieved an acceptable result with Mean Absolute Error (MAE) of 5.855 mg/dL. The result then could be stored in the online database using Cloud Firestore.

Eko Agus Suprayitno et al.[17] propose a non-invasive blood sugar level monitoring system based on the Max30100 and IoT. The glucose level saturation is predicted using linear regression model. The work by Rachel J.

Dotson et.al [18] states that Cholesterol is well known for altering membrane and tissue permeability and physical characteristics. The author suggested that the total solubility of oxygen within the membrane is affected by high cholesterol concentration.

2.2 Commercial device:

Table 2.1: Literature review of Commercial devices

Device	Features	Limitations
FORA Test N'GO Advance Voice Kit	Voice-guided glucose monitoring.Bluetooth-enabled data transfer.	Only monitors glucose.Invasive testing requiring finger pricks and test strips.
Accutrend® Plus System	Measures glucose, cholesterol, lactate, and triglycerides.Lightweight and portable.	Invasive testing requiring blood samples.Expensive
CURO L5	Measures glucose and cholesterol.Fast results in 2 minutes.	Invasive testing.No app-based caregiver integration.
Wellion GALILEO GLU/CHOL	Measures glucose and cholesterol.Large display and portable design.	Cholesterol test takes 90 seconds. High blood sample.

FORA Test N'GO Advance Voice Kit

LipidPlus Professional Lipid and Glucose Analyzer

Accutrend® Plus System

.CURO L5

Fig 2.1 : Commercially available device

Chapter 3

Methodology

3.1 System Flow-chart:

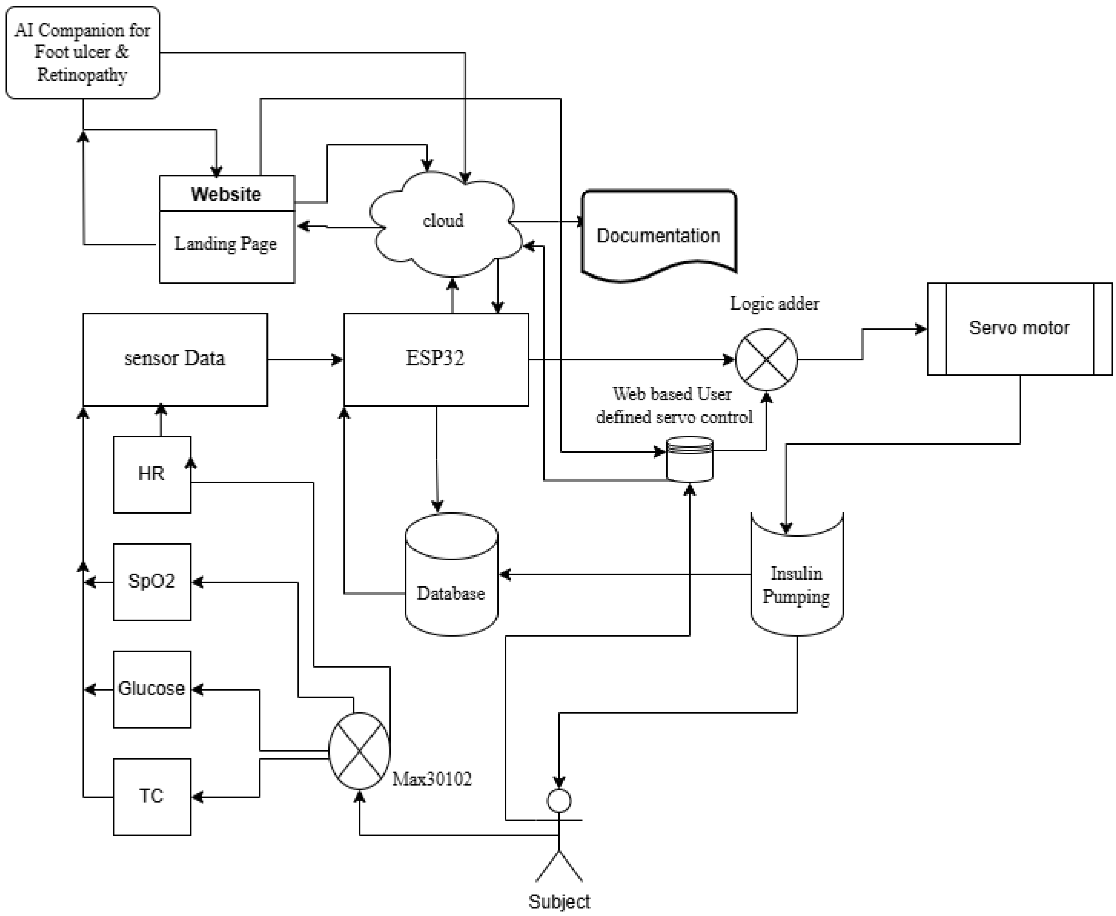


Fig 3.1: Total system flow chart

The whole system is powered by an ESP32 microcontroller operating at a supply voltage of 5 volts. The ESP32 is used here because of its very low power consumption, superior processing capabilities, and lower cost compared to the Arduino Uno R3. The MAX30102 is used for the acquisition of physiological data, including heart rate (HR), SpO2, glucose levels, and cholesterol levels, owing to its superior performance relative to the MAX30100 and its cost-effectiveness compared to subsequent models such as the MAX30105. The data is sent to the ESP32, which utilizes the linked Wi-Fi to upload it to the cloud. The web application retrieves this data from the cloud and regulates the servo motor to administer insulin at the appropriate amount based on the glucose concentration. The servo motor regulating the insulin pump may be regulated via an application based on user-defined parameters. The residual insulin in the syringe may be readily quantified. The web app is facilitated with AI based retinopathy and diabetic foot ulcer detection system.

3.2 Electronics Components:

3.2.1 ESP32:

ESP32 is a microcontroller which is facilitated with built in WIFI and Bluetooth functionality on the board. It consumes lower energy, has BLE or Bluetooth Lower Energy, Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC). It has built in capacitive touch sensor and also Hall effect sensor incorporated on board. ESP32 has on board two cores which have 240MHz for each and having Tensilica Xtensa 32-bit microprocessor also [16].

Fig 3.2: ESP32 (Courtasy: Roboticsbd.com)

3.2.2 Max30102:

MAX30102 is a commercial optical sensor that has two LED having 690 nm wavelength and 940 nm wavelength associated with photodiode. All those are printed on a single circuit board and positioned such way that finger can be placed on the LEDs and photodiode interface. The physical specification of MAX30102 is 5.6mm x 3.3mm x 1.55 mm, and consumes very low power which is < 1mW. The supply voltage is 1.8 volt or separated 3.3 volt. The ultra-low shutdown current of 0.7uA [17].

Fig 3.3: MAX3012 (courtesy: internet)

3.2.3 Servo motor:

Servo motor is used here MG996R, which can rotate 180 degree and its dimension are 40.7 x 19.7 x 42.9 mm and its stall torque is 9.4 kg/cm to 11kg/cm. Its operating speed at 4.8 V is 0.19sec/60 degree. Its operating voltage is 4.8 ~ 6.6 V. Gear is metallic built.

Fig 3.4: MG996R Servo motor (Courtasy: Techshop bd.com)

3.2.4 Fast charging module:

Fast charging module for 12 volt battery charging is used to power up the 5 volt power supply module for constant power supply to the board. It operating voltage is 9 to 12 volt when the output can be varied from 5 to 12 volt.

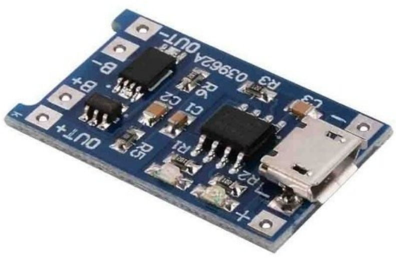


Fig 3.5: Fast charging module (Courtasy: Techshop bd.com)

3.3 CAD modeling:

For prototyping, a Computer Aided design is done in solidworks and the design is visualized and studied in details to find out the feasibility of the CAD model.

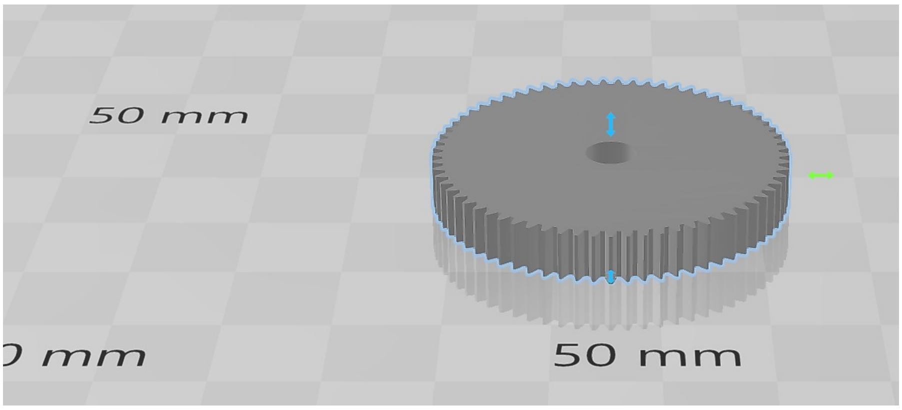


Fig 3.6: Pinion gear designed in soldiworks

Design is sophisticatedly done with proper measuring of the tooth and pressure angle. The pressure angle is 20 degree and the number of tooth is 40. The module is 0.7 in solidworks.

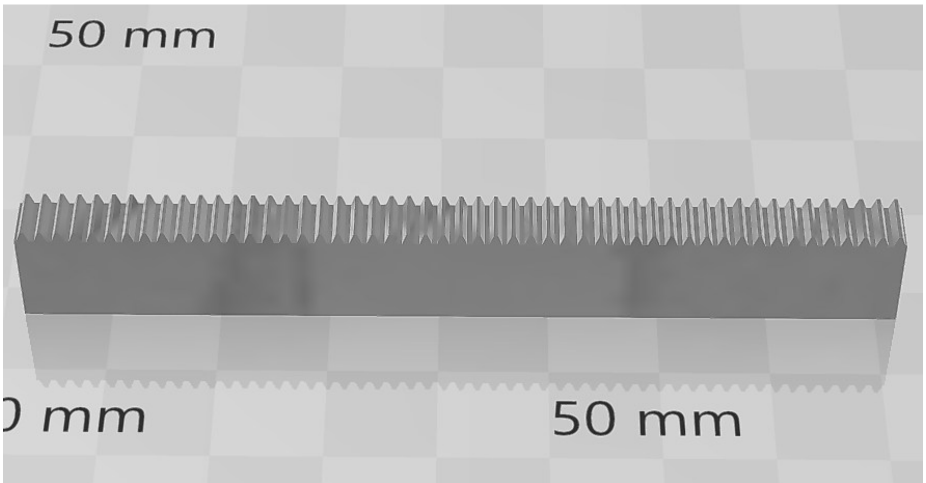


Fig 3.7: Racker Design in solidworks

The Racker-pinion design is done with the calculation of load carried by the front head of the pusher rod. The Racker length is calculated based on the length of the syringe pusher and the linear displacement of the spur gear for a single 180 degree rotation.

$$L > x + l$$

Here x is the length of syringe pusher and l is the linear displacement of the pusher rod for a single 180 degree rotation of the servo motor. The pressure angle of the racker is 20 degree as it is used for the spur gear.

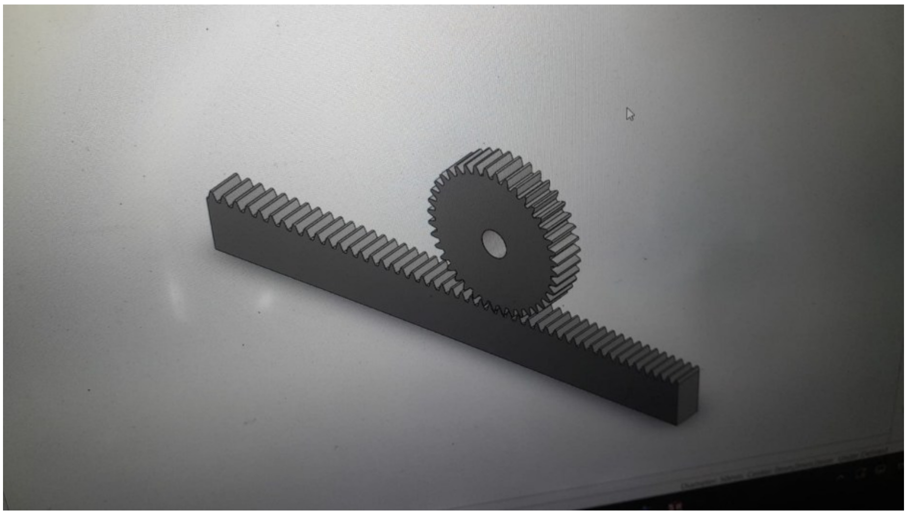
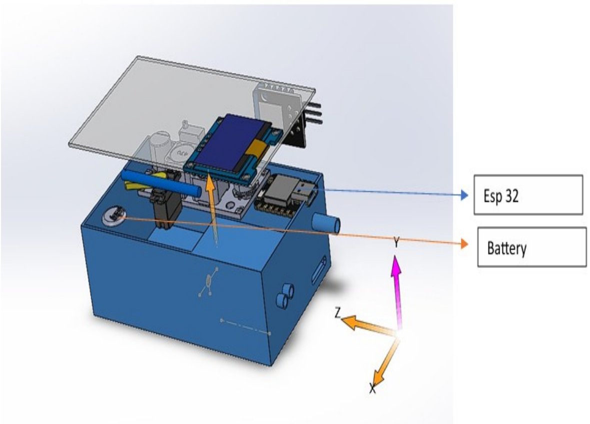


Fig 3.8: Assembly design of Racker-pinion system

The motion study is done after the assembly which shows the greater feasibility of the system. After this motion study , the design was sent to the 3D print in FABLAB, KUET.



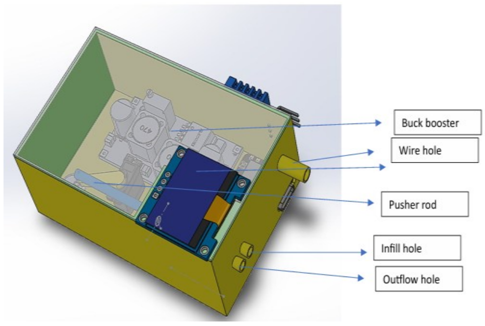


Fig 3.9: Module box design with complete assembly at early design stage.

This is the first design of the diatracker box using SolidWorks. This enclosure is intended to house the circuit components. This will provide a display box for real-time updates for the user. The design has enough airflow and an insertion hole for effective device maintenance. The design was completed for the compatible 3D print at an early stage.

3.4 Circuit Design:

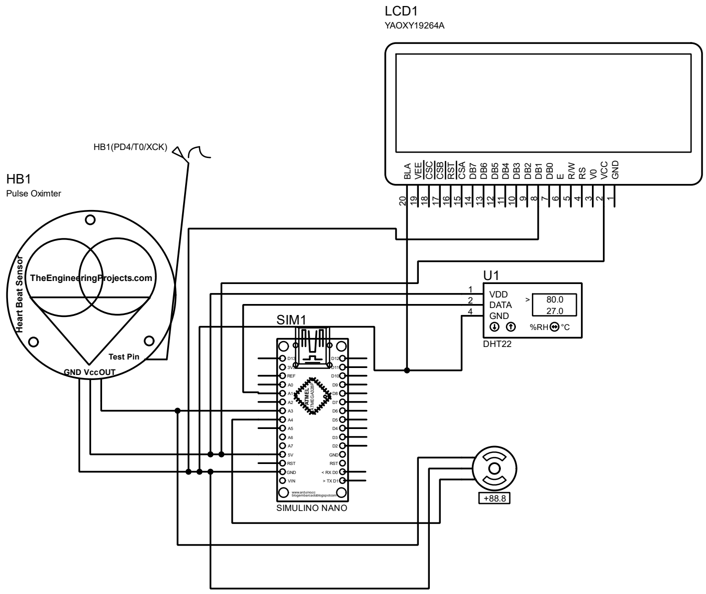


Fig 3.10: Circuit design of diatracker module in proteus.

This design focuses on a conceptual approach, since the requisite sensor library is unavailable in Proteus. The objective of this design is to evaluate the practicality of the implemented gadget. In this instance, the Arduino Nano is used owing to the absence of an appropriate ESP32 library in Proteus, despite its comparable power consumption capabilities to the ESP32.

3.5 App UI/UX design:

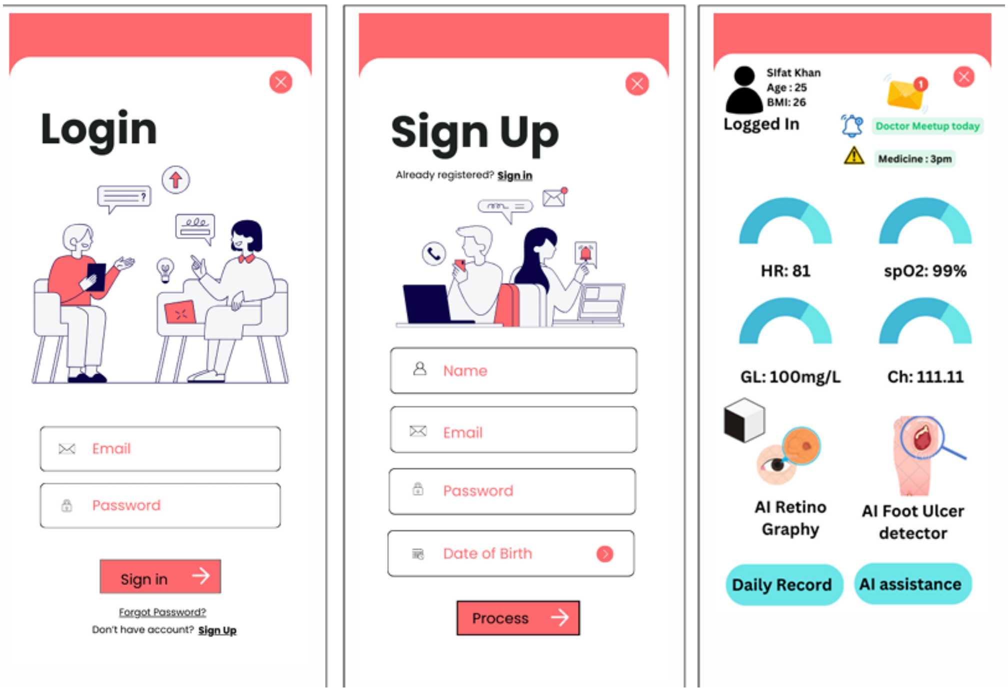


Fig 3.11: Proposed design of UI/UX for diatracker app.

The design aimed to enhance precision and user-friendliness in UI and UX via effective data presentation and capture. The UI/UX design is executed using Figma and Canva.

Web app developed using python flask. The code is written in python and html format and file structure is : project file

- →template
- →index.html
- →login.html
- →signup.html
- →profile.html
- →static
- →style.css
- →app.py

The app.py file is run on the local host : http://127.0.0.1:5000/

Then the file is upload into the GitHub and using render website for deployment. For Database purpose here used SQL-LIGHT.

Fig 3.12: Snippets of code in pycharm

3.6 Art of approach:

3.6.1 Servo motor:

The servo motor depends on the voltage applied here. The mathematical equation is given below.

$$V = IR + L\frac{dI}{dt} + K_b\omega$$

Here,

V is voltage

I is current

R is the resistance

w is the rotational velocity

3.6.2. Racker-pinion mechanism:

The basic equation of the racker pinion is the displacement of the racker due to the servo motor torque.

$x = r \cdot \theta$; Here x is the displacement of the racker due to the spur gear radius r.

The linear velocity of the racker is calculated using

$v = w.r$ Here the w is the rotational velocity and r is the radius of the spur gear.

3.6.3 MAX30102 sensing principle:

Light Emission and Detection:

- The MAX30102 emits light using two LEDs:
- Red LED (660 nm) for oxygenated and deoxygenated hemoglobin.
- Infrared (IR) LED (880 nm) for deeper tissue penetration and detection of blood volume changes.
- A photodetector measures the amount of light that is absorbed or reflected.

Absorption Characteristics:

- The absorption of light depends on the relative concentration of oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb):
- HbO_2 absorbs more infrared light and less red light.
- Hb absorbs more red light and less infrared light.

Signal Modulation:

Blood flow through arteries varies with the cardiac cycle, creating an AC component due to pulsatile blood flow and a DC component due to non-pulsatile tissue and venous blood.

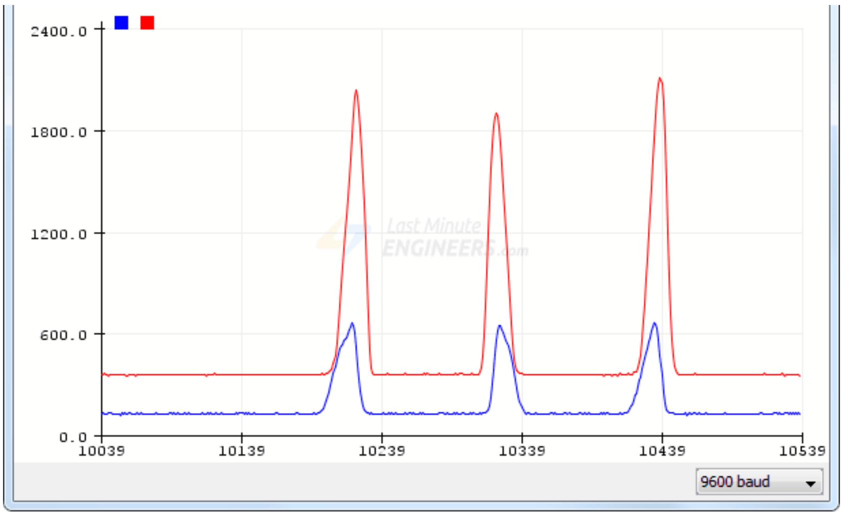


Fig 3.13: Plotting the characteristic curve for red and ir led in max30102

3.7 Syringe control algorithm:

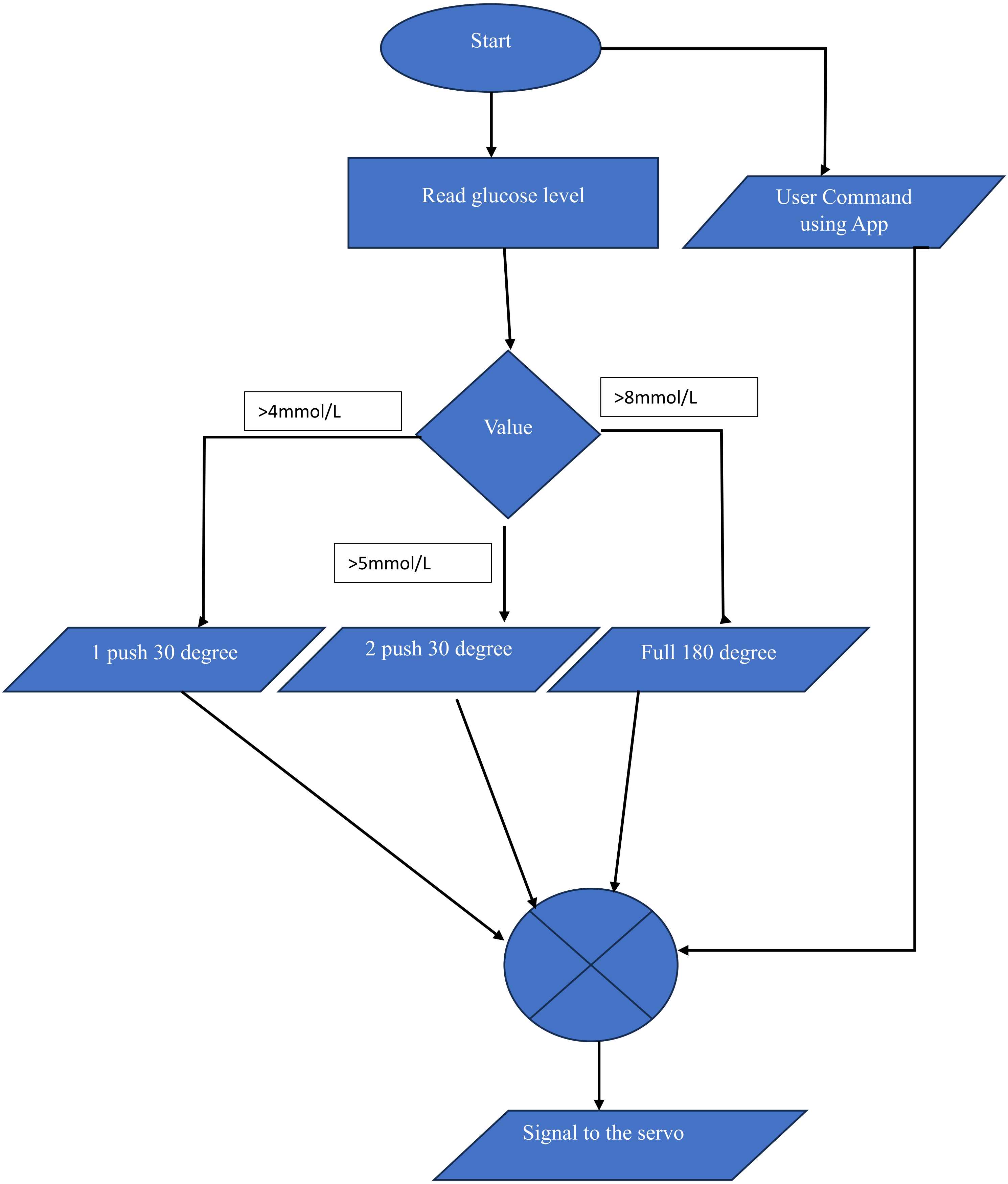


Fig 3.14: Servo motor control logic

3.8 Implementation:

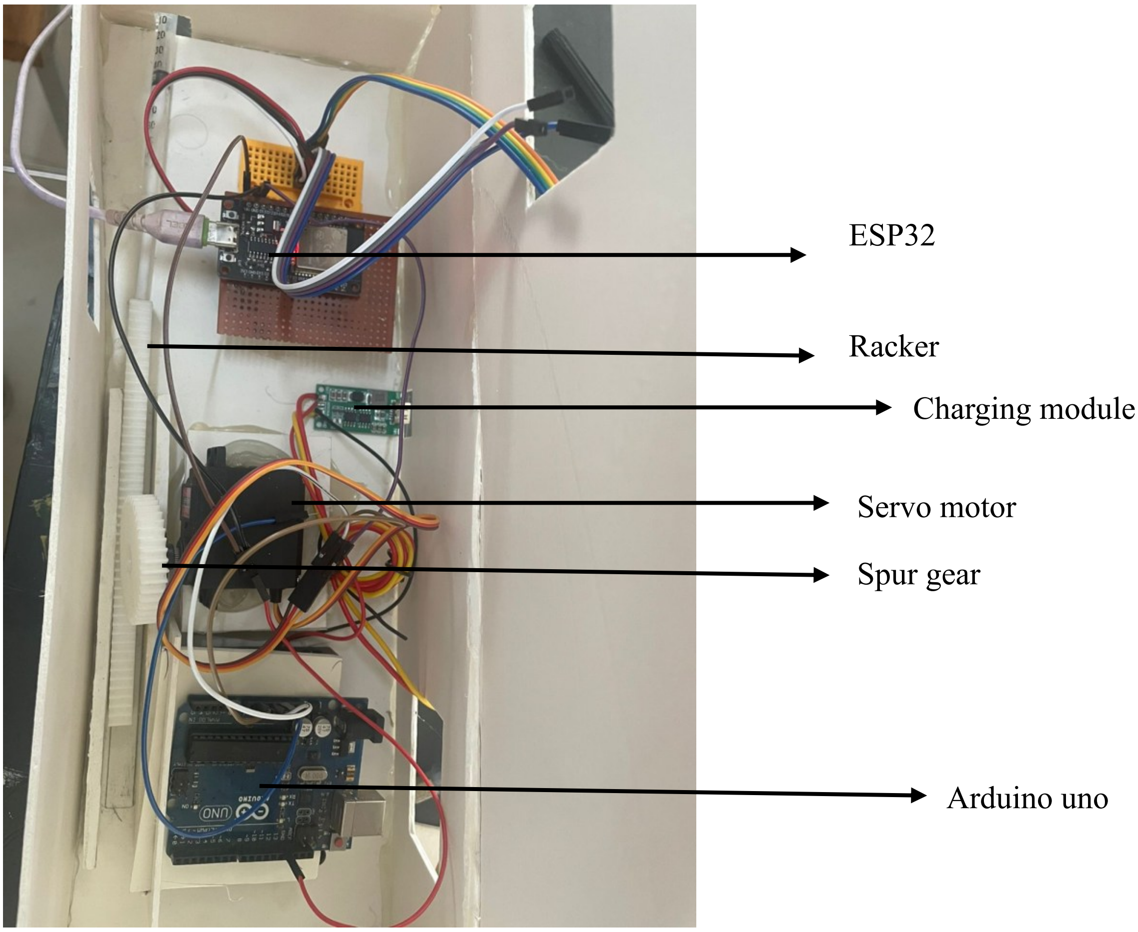


Fig 3.15: Complete setup of the diatracker box

The whole configuration is executed inside the plastic wood cutting box as a result of the cost-reduction strategy associated with 3D printing. It offers a lightweight and portable design; nevertheless, it also presents the drawbacks of a fragile construction and cumbersome form. All electrical equipment and the rack-and-pinion system are contained inside this enclosure.

Fig 3.16: 0.96’ OLED display (left) and fast charging module(right)

Fig 3.17 : Soft textile coated Max30102 sensor for comfort feeling

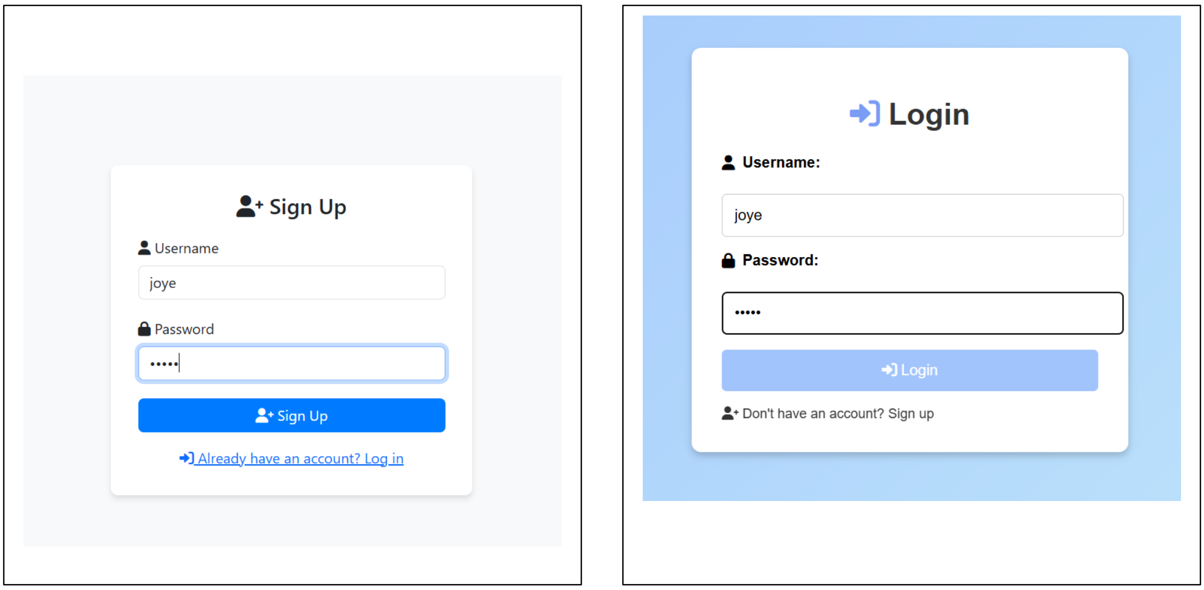


Fig 3.18: Signup and login form

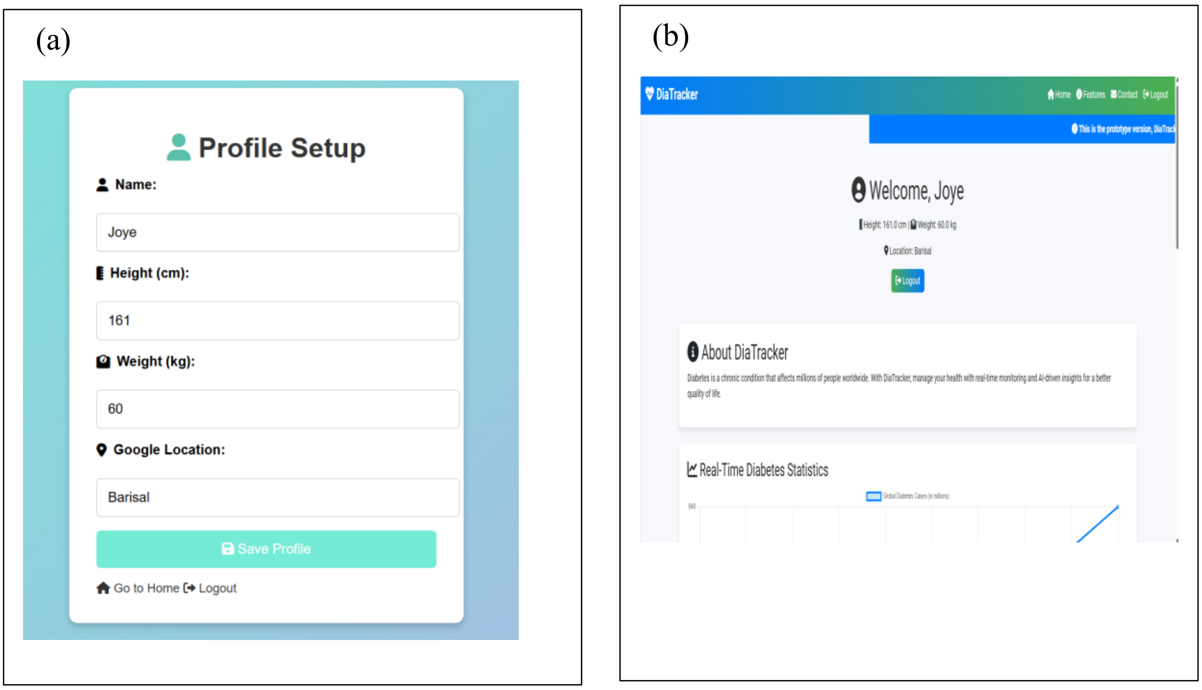


Fig 3.19 : (a) Profile setup site (b) Landig page

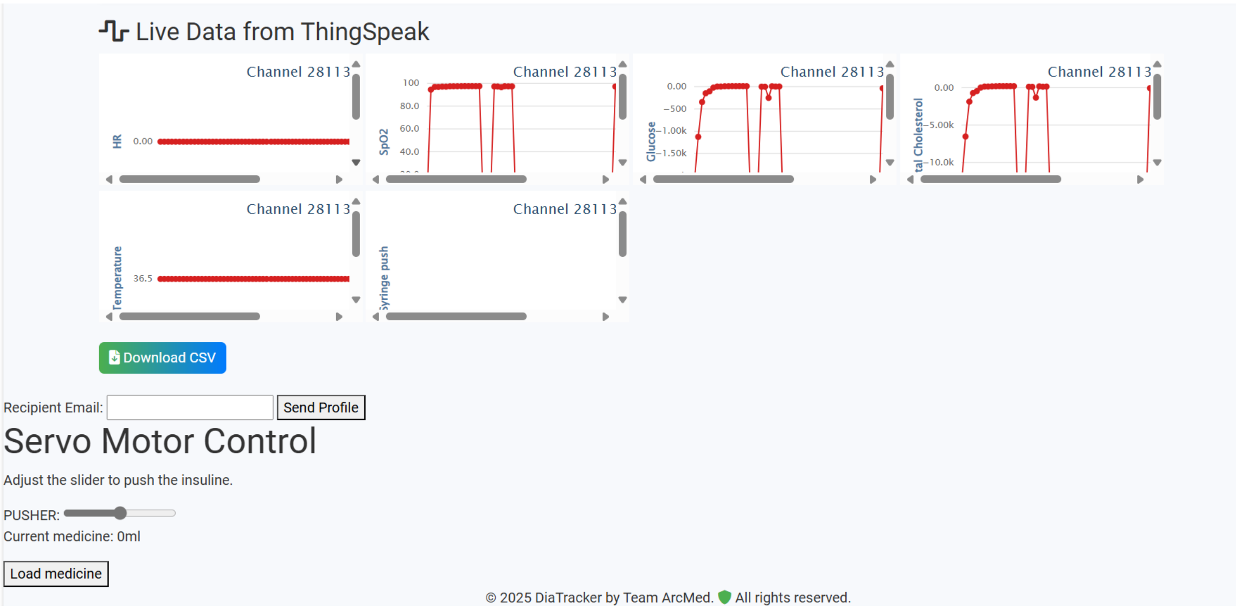


Fig 3.20 : Data Taking and servo control portion of app.

3.8 Glucose and Cholesterol level measure:

Here in the MAX30102, simultaneously photodetector provide the value of response from Red and IR led. First of all, The patient glucose and total cholesterol data collected in Pathology Lab, KUET Medical Center and at the same time the response for both light wave is collected and noted from our device. Then The correlation is checked and regression equation is formulated.

Fig 3.21 : Glucose and Cholesterol data collection in pathology lab, KUET Medical Center.

Four subjects provided data via the signed permission form presented by the research investigators. No patient was hurt or complained discomfort throughout the data gathering process.

Table 3.1: Collected Data for finding the regression equation for both glucose and cholesterol

Subject Name	**Weight**	**Height**	**IR Value**	**Red Value**	**SpO2**	**HR**	**Cholesterol Data**	**Glucose Data**
Lavlu	82	5.5'	93586	117599	98.3	76	150 mg/dL	6.5 mmol/L
Arnab	71	5.7'	91847	117566	99.43	88.34	140 mg/dL	5.0 mmol/L
Maliha	51	5.0'	97157	118190	99.01	88.24	135 mg/ dL	4.0 mmol/L
Sifat	88	5.4'	74504	101360	97.76	88.11	185 mg/dL	5.0 mmol/L

3.9 HR and SpO_2 Value correction:

In medical center of KUET, subjects with proper consent form were asked to provide HR and SpO_2 data in commercially medical grade pulse oximeter and also in our prototyped device. Data collected from the subjects are in the range of 23(+/-2) years old and weight range is 50 kg to 85kg. Subjects were asked provide data in three form: (a) Resting (b) Normal (c) Working. Then the collected data is analyzed to find out the correction factor.

Fig 3.22: SpO2 and HR data comparison with medical grade device

Table 3.2: Commercial vs prototyped device data comparison

Commercial SpO2	Our Device SpO2	Commercial HR	Our Device HR
Working			
93	95	92	96
93	98	96	90
95	95	99	96
95	98	75	63
96	99	70	75
96	99	70	81
95	95	99	95
95	93	90	90
95	93	93	89
98	98	80	88
98	98	83	86
98	98	78	80
98	98	89	85
98	97	85	85
98	98	90	88
Normal			
99	99	87	85
99	99	84	85
99	98	98	104
100	99	63	72
99	99	70	72
99	99	77	80
98	97	88	87
98	97	84	85
98	98	88	86
99	99	86	88
99	98	92	92
99	97	93	95
99	99	65	66
99	99	68	66
99	98	60	62
Resting			
95	98	78	81
96	98	86	86
96	96	87	86
98	99	64	68
98	94	72	68
98	98	61	60
98	98	65	62
98	93	74	75

98	97	76	78
97	96	61	61
98	96	65	66
98	98	64	60
100	99	71	76
100	99	71	74
99	99	70	68

Chapter 4

Result

The prototyped gadget works well upon final configuration. The first assessment of the MAX30102 sensor data confirms the device's functionality.

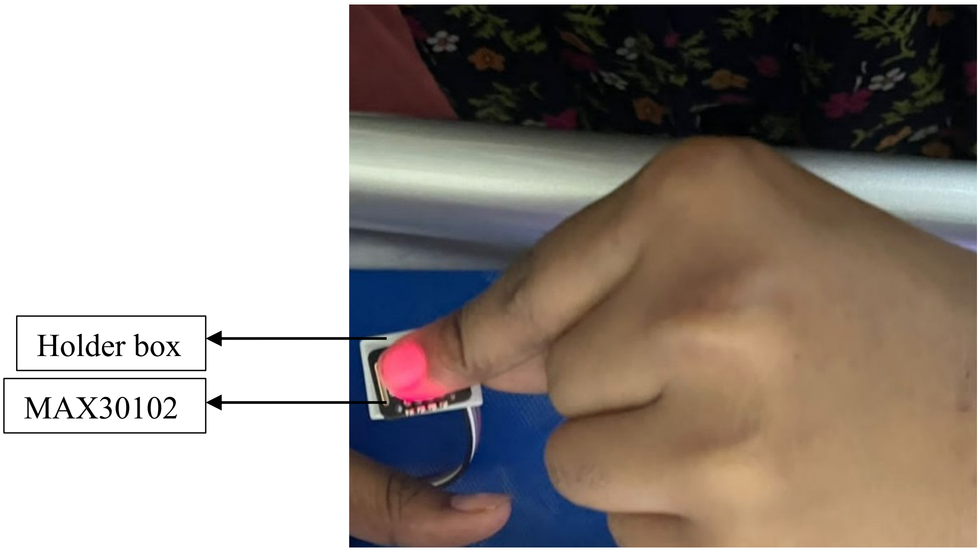


Fig 4.1: MAX30102 is perfectly working

The MAX30102 is encased in a textile material that ensures comfort for the user. The subjective opinion-based numbering was conducted, and the comfort level was assessed. Participants are chosen at random.

Table 4.1 : Subject opinion of Textile finishing on the MAX30102 and holder box

Subject Serial	% of comfort	Remark
01	85	Should be more compact
02	90	Should be more soft
03	80	-
04	80	-

According to the table 3.2 the correction factor for the HR and SpO_2 is calculated and find out the correlation and regression curve. This correction factor would be used for enhancement the data accuracy and provide better result.

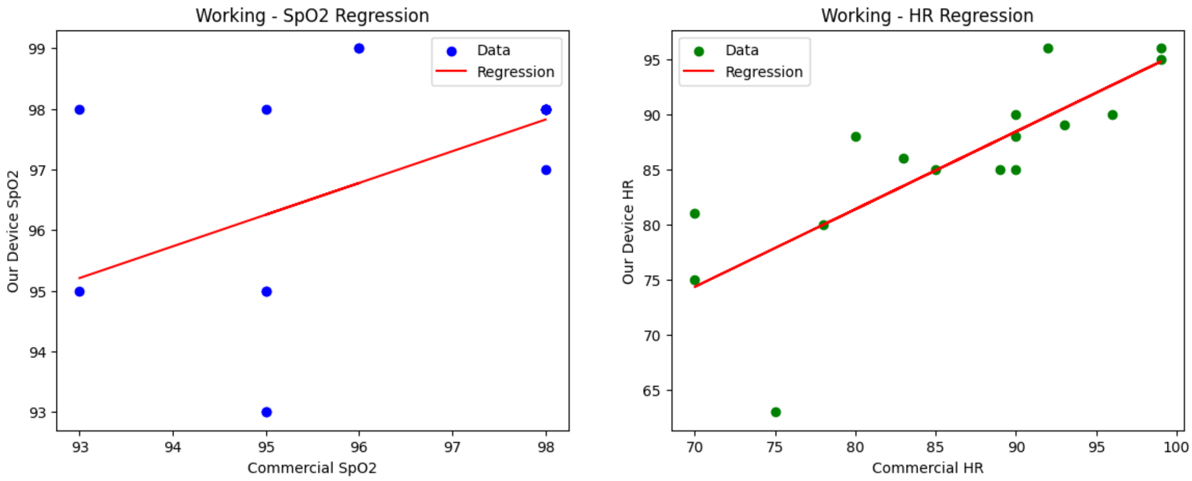


Fig 4.2: In the time of working condition

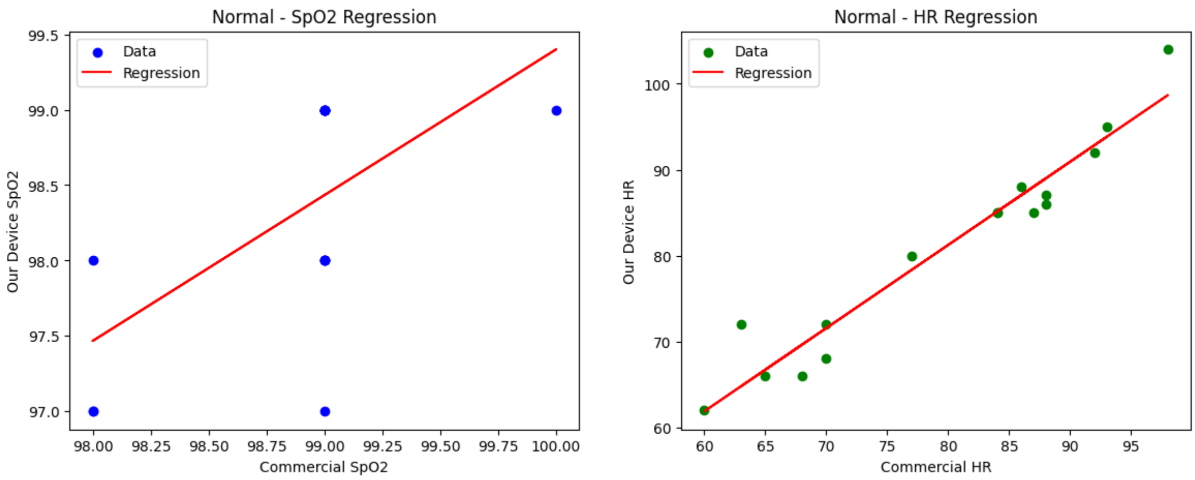


Fig 4.3: In the time of normal condition

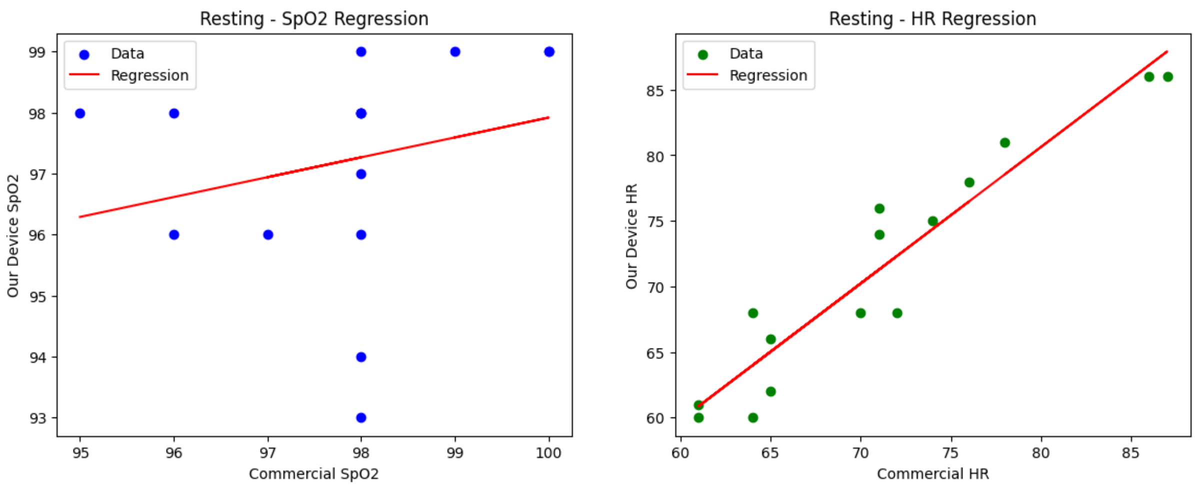


Fig 4.4: In the time of Resting condition

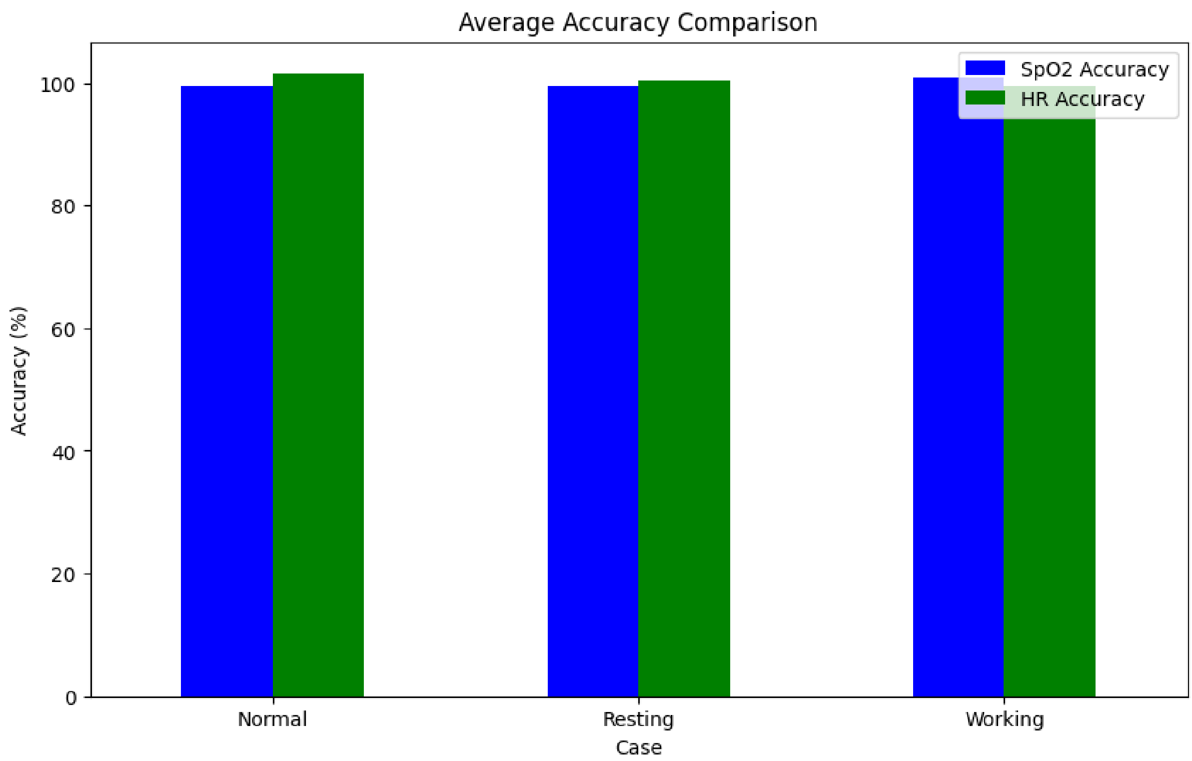


Fig 4.5: Accuracy level for each of three cases

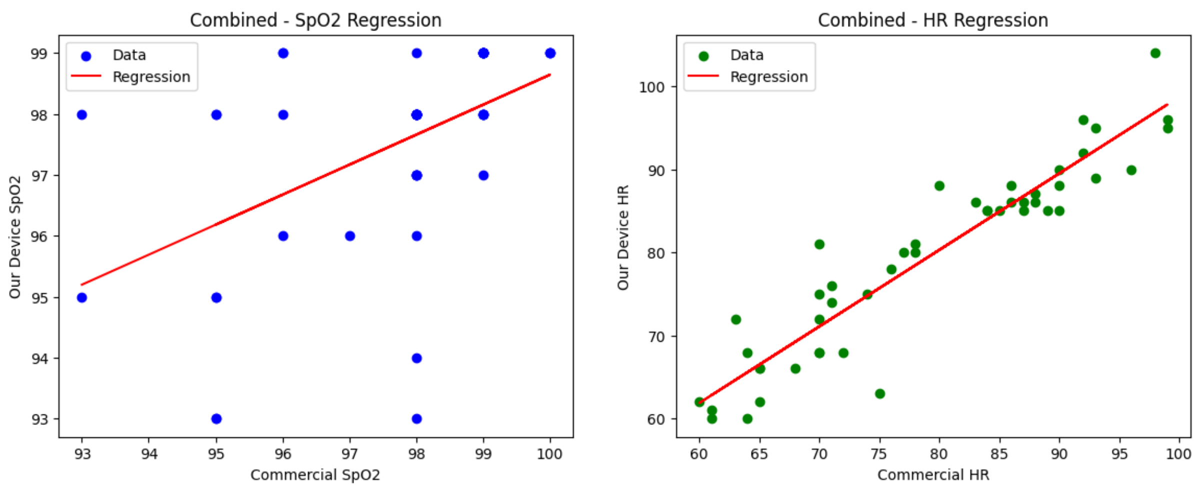


Fig 4.6: Regression for combined the data of each case

According to the table 3.1 the regression equation is found for measuring glucose and cholesterol level. Besides, correlation factors are also analyzed here. Converging curve also analyzed for finding out the convergence level of accuracy.

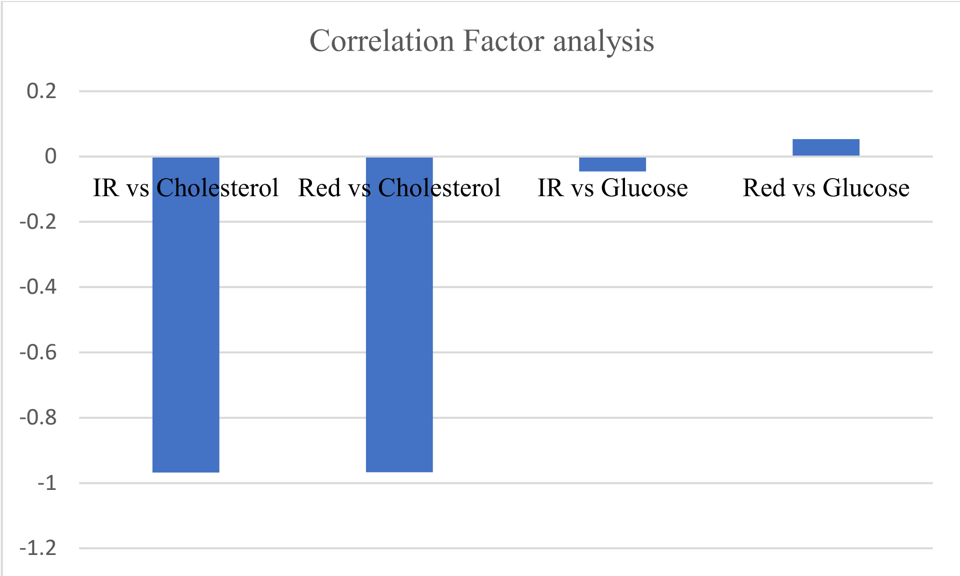


Fig 4.7: Correlation factor analysis for glucose and cholesterol value

After analyzing the table 3.1, using python runtime, the regression equations are :

Cholesterol Equation: y = 626.5942 + -0.0000*1 + 0.0000*IR_Value + 0.0000*Red_Value + -0.0000*IR_Value^2 + 0.0000*IR_Value Red_Value + -0.0000*Red_Value^2

Glucose Equation: y = 55.0157 + -0.0000*1 + 0.0000*IR_Value + 0.0000*Red_Value + -0.0000*IR_Value^2 + 0.0000*IR_Value Red_Value + -0.0000*Red_Value^2

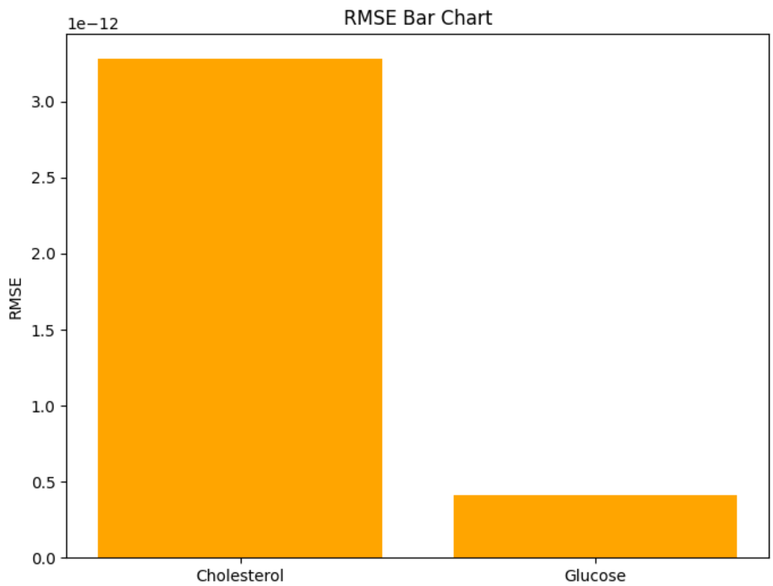


Fig 4.8: RMSE bar chart for the regression equation for both cholesterol and glucose value

The result is also perfectly run in the serial monitor of Arduino IDE and the data is observed properly. The data is in the range of better range.

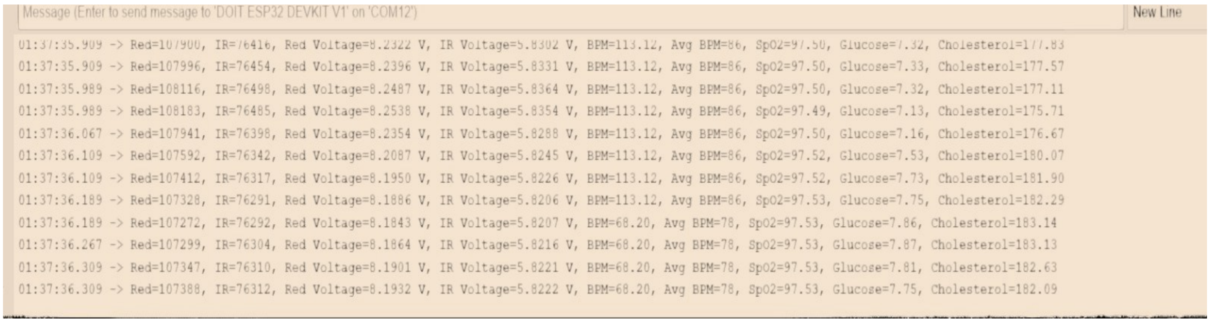


Fig 4.9: Value HR, SpO2, Glucose, Cholesterol shown in serial monitor

The integrated Web app perfectly fetched the data from cloud using proper login and signup system which would ensure the data safety of the patient. Web app is facilitated with AI classification system for DR and DFU. Here CNN model is used for the classification of DR and DFU.

Fig 4.10: DFU and normal foot

Here EfficientB0 is used as the model. The training status of the model is

```
Total params: 4,057,253 (15.48 MB)
```

```
Trainable params: 4,012,670 (15.31 MB)
```

```
Non-trainable params: 44,583 (174.16 KB)
```

Fig 4.11: Training Status of the model

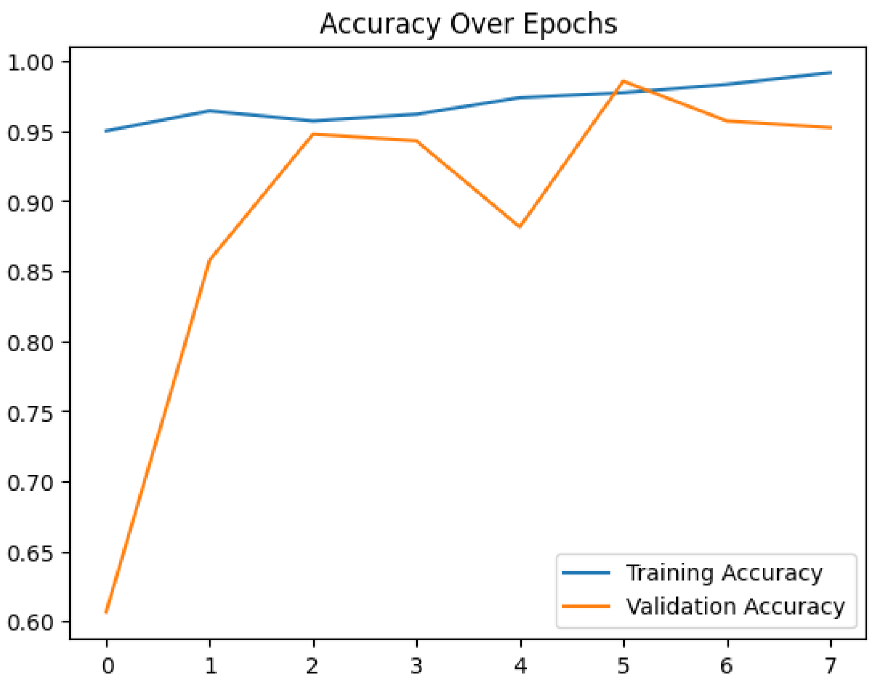


Fig 4.12: Training and validation accuracy of the model

For simplicity of the prototyping here only efficientBO model is trained and tested. For better accuracy it needs to be more tuned.

In the web-app classification is done by uploading image and the model run in the behind and classify the image.

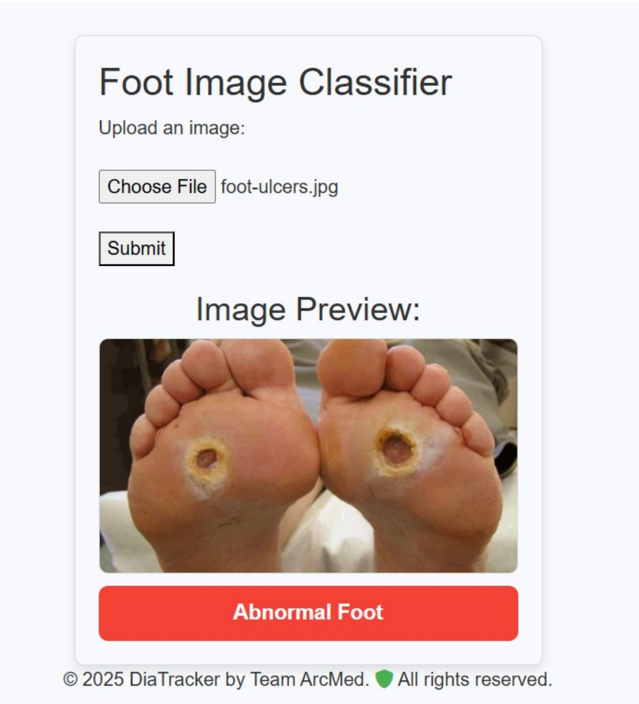


Fig 4.13: Foot ulcer classifier integration in web app.

From the observation it is seen that 60-65% it provides the accurate result for new uploaded images.

Data can be easily sent to the doctor using emailing system integrated in the webapp.

Fig 4.14: Profile sending to the doctor integrated in webapp

Table 4.2: Gantt chart of project implementation pipeline

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Idea development								
Component testing								
Circuit Implementation								
App development								
Integration								
Data collection								
Final Setup								

Chapter 5

Discussion

The project has insulin infusion and a diabetes tracking online application. The web application is equipped with an AI-based DFU classifier. The majority of diabetes tracking initiatives concentrate only on one or two aspects, such as glucose monitoring, infusion pumps, or app-based tracking. This diatracker project aims to merge an infusion system with a non-invasive glucose and cholesterol measuring device. The glucose and cholesterol measuring system use regression analysis based on data gathered from the pathology laboratory of the KUET medical center. However, the number of subjects is limited owing to financial constraints and insufficient project implementation time. The data is not compared with sufficient precision, resulting in a significant RMSE value. To achieve this objective, the project must be outfitted with LEDs emitting light at 990 nm for glucose detection and 425 nm for cholesterol detection, followed by the formulation of a regression equation to ascertain the levels of glucose and cholesterol. To enhance the accuracy of formularization in the current situation, it is essential to focus on identifying the correlation and regression equation. Cholesterol has a negative correlation with both insulin resistance (IR) and red LED, whereas glucose shows a positive correlation with red LED. The regression equation for glucose testing in relation to the RED LED value would provide superior results. The correction factor for both HR and SpO2 indicates that it yields favorable results post-adjustment. The HR exhibits a stronger correlation between the diatracker prototype device and the commercial device, but the data are inconsistent. Conversely, SpO2 requires further adjustment based on more observational data. The Diatracker online application requires enhanced security via the use of blockchain technology, in addition to using natural language processing for communication with physicians and stakeholders. The UI/UX must be more user-friendly in the beta version of the launch or during real-world operation. The insulin infusion system operates on the rack and pinion mechanism. This technique exhibits superior precision in actuation; nonetheless, it often results in the degradation of pinion teeth owing to collisions. In reality, an other propulsion system is required to circumvent this collision. The module box should be more user-friendly, aesthetically appealing, and compact for easy transport when walking or jogging. The textile finishing of the MAX30102 should be more precise and compact to enhance user comfort and ensure proper finger placement. The implementation of the online application is impeded by technical difficulties and server complications. It must be implemented in a practical, real-world setting.

Chapter 6

Prospect and Conclusion

6.1 Prospect :

The prospect of the project are given below:

1. Circuit need to be housed in PCB
2. Microcontroller need to be used more medical graded
3. Sensor will be updated by using extra two LED for detecting glucose and cholesterol
4. More subject will be added to find out the better regression and correlation analysis.
5. Housing of the project need to be more smaller and stronger for better carry.

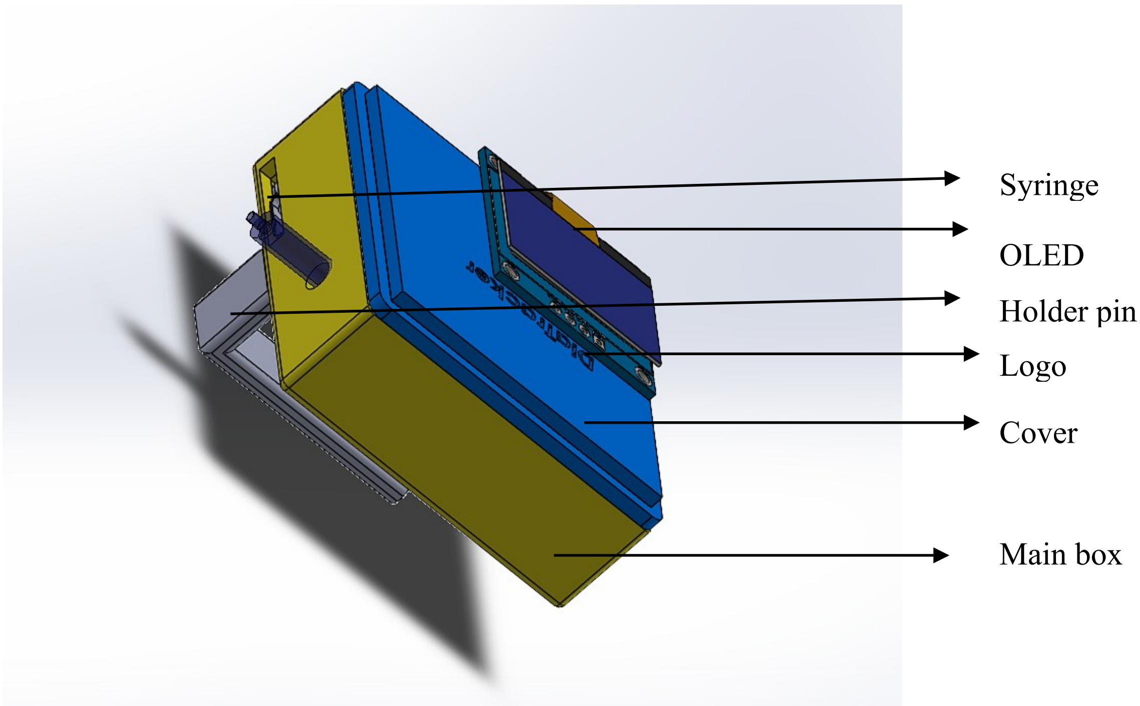


Fig 6.1: Minimalistic & easy carrying design for real life implementation

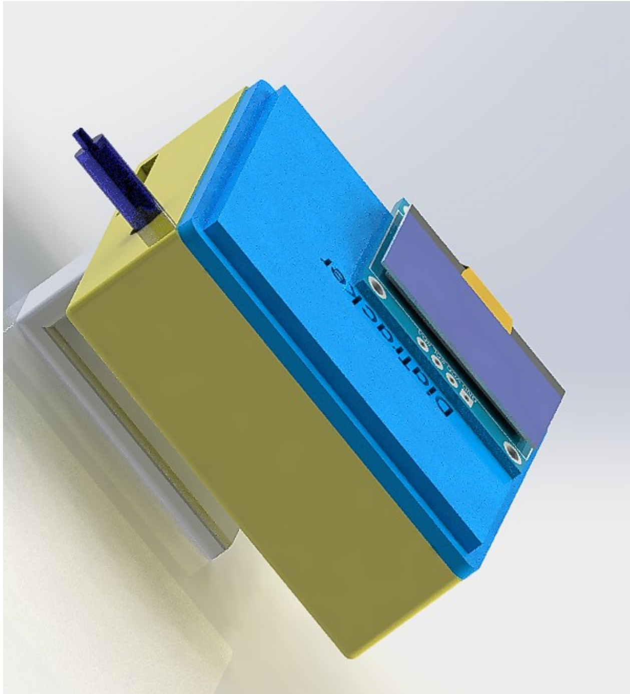


Fig 6.2: Rendered view of Diatracker Device V2.0

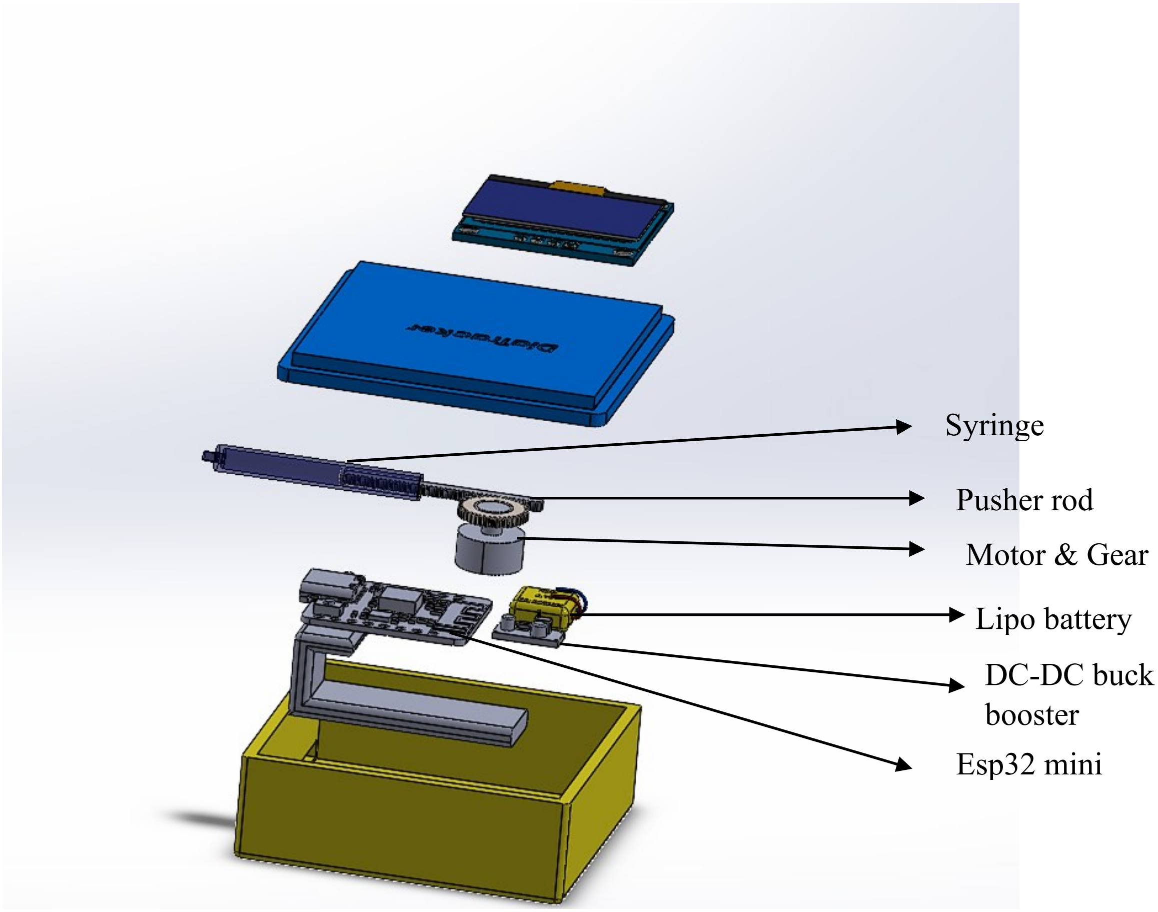


Fig 6.3: Exploded View

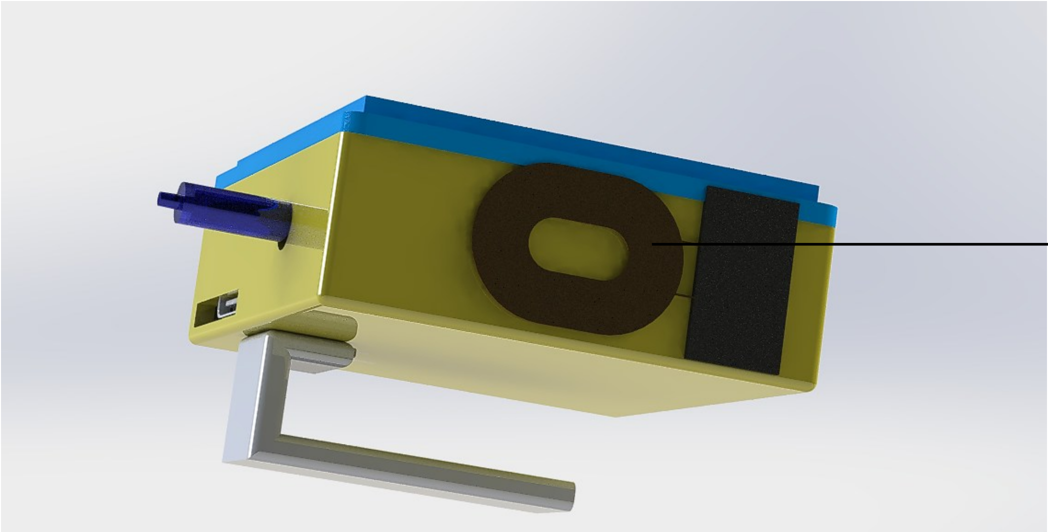


Fig 6.4: Upgradation of charging module by wireless system.

In future PVDF based Electroactive polymer will be used here for pushing mechanism of the syringe. It needs high voltage but low power to deform the polymer and it can be used for pushing mechanism of syringe.

PVDF is a piezoelectric polymer, meaning it deforms when subjected to an electric field. The fundamental equation governing the strain (ε) induced in PVDF due to an applied electric field (E) is:

$$\varepsilon = d_{33}E$$

where:

- ε = Strain (dimensionless)
- d_{33}= Piezoelectric strain coefficient (m/V)
- E = Electric field applied (V/m\text{V/m}V/m)

The required voltage will be :

$$V = \frac{30t}{d_{33}L}$$

Simulation has been performed in python3 environment. But for proper visualization and with more consideration, it need to be simulated in COMSOL like platform.

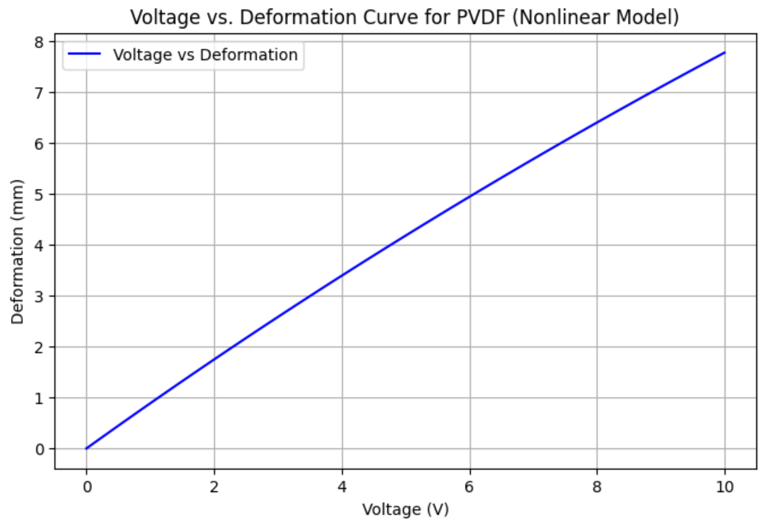


Fig 6.5: PVDF based Electroactive polymer simulation with respect to the applied voltage..

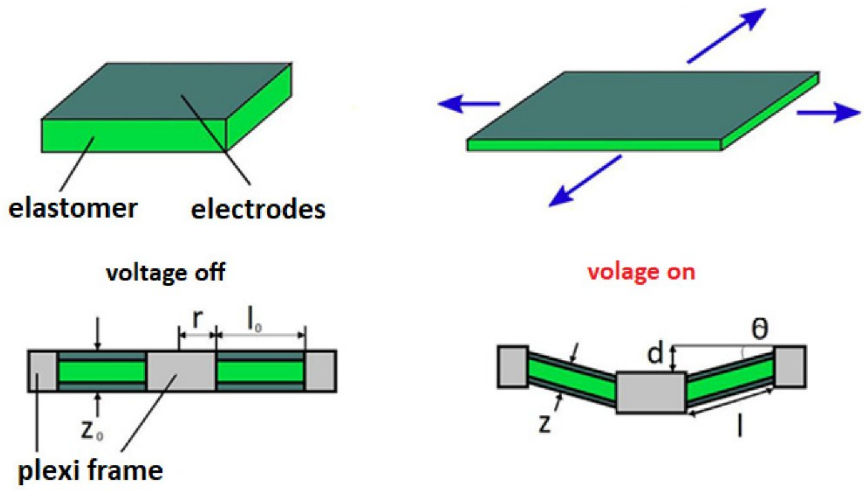


Fig 6.6: Mechanism for Dielectric Polymer based pump.

6.2 Conclusion :

The project effectively combines the 30102 sensor, ESP32, Arduino Uno Mini, and a servo motor to create a system characterized by efficient functioning and controllable power consumption. The overall power consumption is roughly 3.15W, and the system produces approximately 11.34 kJ of heat during one hour of operation.

This result underscores the system's viability for sustained operation with no thermal issues, guaranteeing dependable performance in practical applications. Future improvements may concentrate on maximizing power efficiency, minimizing heat production, and augmenting the system's capacity to manage more intricate jobs or supplementary components.

Appendix

Code for ESP32:

```
#include <Wire.h>

#include "MAX30105.h"

#include "heartRate.h"

#include <ESP32Servo.h>

#include <WiFi.h>

#include <HTTPClient.h>


// WiFi credentials

const char* ssid = "sifat";

const char* password = "12345678";


// ThingSpeak API Key

const char* writeAPIKey = "BMZLQSJVCSJGXH8M";

const char* server = "http://api.thingspeak.com/update";


MAX30105 particleSensor;

Servo myservo; // Create servo object


const byte RATE_SIZE = 4; // Increase this for more averaging. 4 is good.

byte rates[RATE_SIZE];    // Array of heart rates

byte rateSpot = 0;

long lastBeat = 0;        // Time at which the last beat occurred
```

```
float beatsPerMinute;
int beatAvg;

// Variables for SpO2, glucose, and cholesterol calculations
long redValue, irValue;
float ratio, SpO2;
float redVoltage, irVoltage; // ADC Voltage variables
float glucose, cholesterol;  // Glucose and cholesterol variables

// Servo angle variable
int servoAngle = 0; // Current angle of the servo

// Temperature simulation
float temperature = 36.5; // Simulated temperature value

void setup()
{
  Serial.begin(115200);
  Serial.println("Initializing...");

  // Connect to WiFi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED)
```

```
  {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");

  // Initialize sensor
  if (!particleSensor.begin(Wire, I2C_SPEED_FAST)) // Use default I2C port, 400kHz speed
  {
    Serial.println("MAX30105 was not found. Please check wiring/power.");
    while (1);
  }
  Serial.println("Place your index finger on the sensor with steady pressure.");

  particleSensor.setup();                    // Configure sensor with default settings
  particleSensor.setPulseAmplitudeRed(0x1F);  // Set Red LED to a moderate level
  particleSensor.setPulseAmplitudeIR(0x1F);   // Set IR LED to a moderate level
  particleSensor.setPulseAmplitudeGreen(0);   // Turn off Green LED

  // Attach servo to pin 13 (change to your setup)
  myservo.attach(13);
  myservo.write(servoAngle); // Start servo at 0 degrees
}
```

```
void loop()
{
  // Read sensor values
  redValue = particleSensor.getRed();
  irValue = particleSensor.getIR();

  // Convert to ADC voltage
  redVoltage = (float)redValue / 65535 * 5.0; // Scale red value to 0-5V
  irVoltage = (float)irValue / 65535 * 5.0;   // Scale IR value to 0-5V

  // Heart rate calculation
  if (checkForBeat(irValue) == true)
  {
    // We sensed a beat!
    long delta = millis() - lastBeat;
    lastBeat = millis();

    beatsPerMinute = 60 / (delta / 1000.0);
    beatsPerMinute = 0.9517 * (beatsPerMinute) + 3.3113;

    if (beatsPerMinute < 255 && beatsPerMinute > 20)
    {
      rates[rateSpot++] = (byte)beatsPerMinute; // Store this reading in the array
      rateSpot %= RATE_SIZE;                    // Wrap variable
```

```
    // Take average of readings
    beatAvg = 0;
    for (byte x = 0; x < RATE_SIZE; x++)
      beatAvg += rates[x];
    beatAvg /= RATE_SIZE;
  }
}

// SpO2 calculation
if (redValue > 5000 && irValue > 5000) // Ensure valid readings
{
  ratio = (float)redValue / irValue;
  SpO2 = 110 - (9 * ratio); // Simplified SpO2 formula
  SpO2 = 0.4992 * SpO2 + 48.9357;
  if (SpO2 > 100) SpO2 = 100; // Limit SpO2 to 100%
  if (SpO2 < 0) SpO2 = 0;     // Limit SpO2 to 0%
}
else
{
  SpO2 = 0; // No valid SpO2 if signals are too low
}

// Glucose calculation (based on regression equation)
```

```
  glucose = -3547.7874 + 644.7089 * irVoltage + 385.5214 * redVoltage - 70.3684 * irVoltage
* redVoltage;


  // Cholesterol calculation (based on regression equation)
  cholesterol = -20998.7987 + 3906.7469 * irVoltage + 2286.6576 * redVoltage - 425.5553 *
irVoltage * redVoltage;


  // Servo motor control based on glucose levels
  if (glucose > 4 && glucose <= 5)
  {
    servoAngle = -30; // Rotate to 30 degrees
    myservo.write(servoAngle);



  }
  else if (glucose > 5 && glucose <= 6)
  {
    servoAngle = -30; // Rotate to 30 degrees
    myservo.write(servoAngle);

    delay(500);
    servoAngle = -30;   // Rotate to 30 degrees again
    myservo.write(servoAngle);

  }
```

```
else if (glucose > 6)
{
  servoAngle = 180; // Rotate to 180 degrees
  myservo.write(servoAngle);

}

// Prepare ThingSpeak data
if (WiFi.status() == WL_CONNECTED)
{
  HTTPClient http;
  String url = String(server) + "?api_key=" + writeAPIKey +
             "&field1=" + String(beatsPerMinute) +
             "&field2=" + String(SpO2) +
             "&field3=" + String(glucose, 2) +
             "&field4=" + String(cholesterol, 2) +
             "&field5=" + String(temperature, 2) +
             "&field6=" + String(irValue) +
             "&field7=" + String(redValue);

  http.begin(url);
  int httpResponseCode = http.GET();

  if (httpResponseCode > 0)
```

```
  {
    Serial.print("ThingSpeak Response Code: ");
    Serial.println(httpResponseCode);
  }
  else
  {
    Serial.print("Error Sending Data: ");
    Serial.println(httpResponseCode);
  }
  http.end();
}
else
{
  Serial.println("WiFi Disconnected");
}

// Print results
Serial.print("Red=");
Serial.print(redValue);
Serial.print(", IR=");
Serial.print(irValue);

Serial.print(", Red Voltage=");
Serial.print(redVoltage, 4); // Display 3 decimal places
```

```
Serial.print(" V");

Serial.print(", IR Voltage=");

Serial.print(irVoltage, 4); // Display 3 decimal places

Serial.print(" V");


Serial.print(", BPM=");

Serial.print(beatsPerMinute);

Serial.print(", Avg BPM=");

Serial.print(beatAvg);


Serial.print(", SpO2=");

Serial.print(SpO2);

Serial.print(", Glucose=");

Serial.print(glucose, 2); // Display 2 decimal places


Serial.print(", Cholesterol=");

Serial.print(cholesterol, 2); // Display 2 decimal places


Serial.print(", Servo Angle=");

Serial.print(servoAngle); // Display current servo angle


if (irValue < 50000)

  Serial.print(" No finger?");
```

```
  Serial.println();

  delay(1); // Upload data every 15 seconds

}
```

s

Table of Contents