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An IoT and Cloud Enabled Smart Chair for Detection and Notification of Wrong Seating Posture

Journal of Electrical Systems

Abstract: - Modern-day lifestyle is hugely dependent on the computers as most of the work is directly or indirectly controlled by them. Such machines are reducing the efforts of human beings and improving the human lifestyle by enhancing comfort in doing the work. This enhanced comfort however is making the humans inactive as they tend to sit in one place for many hours. The sitting posture plays a very important role in avoiding the injuries to spine and joints. It gets difficult for the person to know the correct posture while sitting on a chair. In the proposed work, a cloud-based IoT-enabled smart chair is proposed that continuously monitors the seating posture of a person and notifies the person about the wrong sitting position while simultaneously storing the data on the cloud. The database stored in the cloud helps medical doctors to analyze the root cause of the problem related to the spinal or joint. The proposed work equipped with sensors, microcontroller, and cloud-enabled technology offers seamless connectivity and notification thus making the system suitable for any kind of environment.

Keywords: Blynk 2.0; Cloud computing, Embedded System, IoT, Smart Chair.

I. INTRODUCTION

Human body is quintessential for being productive. To be productive, everyone should do certain work. Today, most of the world's population prefers to do the work while sitting in the cubical shaped office of them. To fulfill their responsibilities whether it is social or personal, each one of us are choosing to have a great job with handsome amount of salary. For this, we need to work whole day and night, just like the IT engineers and Government officials. But working whole day just sitting at one place can leave a person for certain long-term effects and diseases. Not only IT professionals, but also some bank worker, stock market brokers and high standard officers contribute a lot in boosting the country's economy by sitting in one position constantly and going through a hard and rough day at office. Ultimately, they will get their desire salary, reputation and promotions, but in spite of knowing the fact that, this kind of hectic job will affect adversely to their body, they are doing it as shown in figure 1.

Figure 1: The problems that occurs in foreseen Future

According to the National Institute of Neurological Disorders and stroke, it is stated that Back pain and joint pain are the most common Job-related disability. Mostly 80% of people are now facing problems related to back pain

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in their entire life span, and 25% of adults ready have a spine and joint problems. The back pain increases due to the stretching of the spinal ligaments. Also, normal office work has an average sitting time of 9 to 10 hours, also, with different postures where 5 postures: i) Upright Position ii) Right leg resting on left thighs, iii) Left leg resting on right thighs, iv) Leaning forward and v) Inclination backward more than 105° as shown in figure 2. [1]

The upright position is considered as a normal sitting position. However, this static posture increases the in the back, shoulders, arms, and legs, and can put a lot of pressure on the back muscles and spinal discs in particular. In the second and third positions, a tarsal tunnel which is the nerve that runs down the leg is been compressed in this both positions, it causes numbness and can cause pain, cramp in legs and can damage knees in the long term run. From the last 2 postures, the lower back of spinal ligaments can be affected after a long time of sitting on inclination at the angle of 10° to 30° from the vertical axis. Also, the Hips and lumbar spine are damaged after sitting for a long time in front of the chair without the back support. [2]

i) Upright position

ii) Right leg resting on left thigh

iii) Left leg resting on right thigh

iv) Leaning forward

v) Inclination backward more than 105°

Figure 2. Common sitting posture [1]

This all problem is rising as the day passes. Moreover, today's generation does not intend to work out to maintain their body fit. Beings, working in a company, whether male or female, all have been suffering from back problems before reaching the age of 40, which is not a good sign. Not only office workers, but students also suffer from the same fate, especially during the COVID-19 pandemic.[3] All the students studying or working from home had to sit 8 hours a day in the same posture for the whole day. We too faced the same problem during those times. To avoid above mention problems, one has to adapt to the seat in the ideal seating position as depicted in figure 3. But, in reality, it is very much difficult to maintain the same posture for a longer period. In this scenario, if we must have a certain mechanism that timely notifies a person regarding his/her wrong posture and gives suggestions to correct it,that may help to avoid problems related to spinal cord and leg issues.

Focusing on the above problem, this paper proposed a concept of a smart chair built using the combination of embedded system and cloud computing. The embedded system includes the STM 32 microcontroller and a few sensors to detect the pressure and inclination of the back. Blynk 2.0 is used as a cloud platform to collect and analyze the data from the sensor. In the proposed work, smart chair system can notify the user to change the position or to stand for a while after a certain period, over the cloud vai the email and mobile notification.

The concept of "Smart Chair" was the requirement of many engineering field corporations to know the basic and ideal sitting posture and also the ideal conditions of the spinal cord and lumbar and hip support to last its help for comfort of humans for longer time. Many intellectuals did a pretty well research in this line particularly, some of them are mentioned below:

In the late 1800s and early 1900s, several design items were identified. Very early, Parow and von Meyer concluded that the ischial tuberosities were the chief points of support in the sitting position because of posterior pelvic rotation. Von Meyer stated that spinal ligaments were not in tension while sitting and that support is required to give lumbar relaxation. He noted that straight-back chairs did not give support to the spinal column. In 1884, Staffel's designed chair had lumbar support and space under this support for the buttocks to slide backward to affect some forward rotation of the pelvis. Here in Figure 3, the hip support and related bones are justified by the center of mass of the body and the inclination.

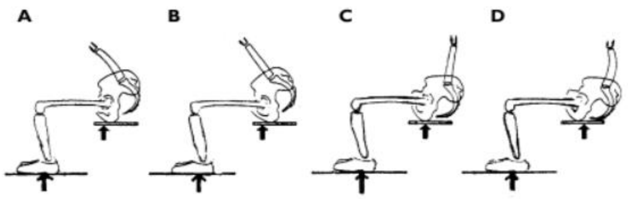

Figure 3: Centre of mass and spine position [2]

After knowing much about what was required for sitting, consulting physiotherapists, came to know that there can be different problems that can arise after sitting in 4 different types of positions which are mentioned in the introduction. In 1953, Keegan noted that seat-bottom height, when too high above the floor, could cause shorter people to have dangling legs. This position causes compression stresses on the soft tissues of the posterior thigh and becomes uncomfortable in a short period. Thus, a short person sitting on a chair that is too high for him or her will soon sit on the edge of the chair and negate any seat-bottom incline or any lumbar support.

The concept of the smart chair resembles Yue Li and Rachid Aissaoui's smart wheelchair which can analyze the trunk flexion angle and pelvic rotation angle along with the pressure while the person is sitting on it. Using linear regression model and Network proposal, they tried to monitor and detect the position of the person. The model measures the sitting position only, not to update the user anything like to change the position and the data was in quantitative and it was not recorded for future analysis [4].

Mayer and the team proposed a chair with a textile pressure sensor for the seating posture classification. Here electrodes are built on both sides of conductive textile material. This structure forms a variable capacitor. Based on different seating postures it creates different pressure systems on the textile pressure sensor. That changes the capacitance of the circuit. It is one of the pioneering works toward detecting seating posture and opens up a new field to monitor human posture for medical treatment. However, due to the limited advancement of IoT and cloud technology at this time, this work does not contain a mechanism for online monitoring and detection system for wrong sitting postures [5].

Jingyuan Cheng and his colleagues did a fantastic job of detecting different positions with an accuracy of 88.06% for 5 subjects and 7 classes, just by placing the pressure sensor at the bottom of the chair's leg. Also, found and detected the subtle hand and head actions like typing, etc. Combining both, they got the real-time data of 4 subjects and 7 classes with an accuracy of 78.3%. They have not used any cloud technology to show real-time data to user which was the limitation of this project [6].

According to Byeong-Gu Ahn and co-authors says that people want to live healthy and immortal life and IoT has been playing an indispensable role in making the health care system much more advanced like Smartphone-based real-time health management solutions. They have studied how postures change affects the bio signal's measurement of person's heartbeats as he/she changes the position. The only limitation of this study was heart rate can be influenced by certain emotions and it may cause an error in reading. Also there is no feedback loop to notify the user for bad posture [7].

Furthermore, an low power consuming Smart chair was made by J. Paek and their team, which was based on separated seating pads so that, sensors on each pad can record the data from a particular data and the program can identify the posture using the Arduino, iBeacon, and Bluetooth network to commute the data from sensor to the smartphone. The sensor used in this study were 6 in number and can read accurate data. Even though, the data of the sensor was not shared via the cloud and no cloud technology is been used. It is for low consumption of power and is not beneficial for long distance communication [8]. The similar product was designed and implemented by Ganesh, Srinu and the team, using the Bluetooth data is been transmitted to the custom android application and then the screen shots and data are sent to the doctor via Email or MMS for quick feedback which was the improvement of the [9] design. The main intention to make this was the reduction of cost but the range and the use of Arduino increased the hardware complexity which was not favorable.

To know whether this chair will improve the sitting posture or not, C. C. Roossien, with the help of pears, got to know that monitoring the sitting position and giving feedback at regular intervals, a 12-week prospective cohort study was done among office workers (Approx. 45) and was regularly given the notification and it was noted that, After turning off the feedback signal, a slight increase in sitting duration was observed (10 min, $p = 0.04$), a slight decrease in optimally supported posture (2.8%, $p < 0.01$), and musculoskeletal discomfort (0.8, $p < 0.01$) was observed. We conclude that the 'smart' chair is able to monitor the sitting behavior, the feedback signal, however, led to small or insignificant changes [10].

Firstly, an automated attendance system was created which was used in schools and universities which help in manual attendance. Using the IoT and from the generated database a student-teacher interaction portal was created to make the institute smarter. But from the database obtained it was found that students had problems in the postures they were sitting on which would, later on, generate complications like Endometriosis, Sacroiliac Joint Dysfunction, Degenerative Disc Disease, and more. So later on, they added a feature regarding improper sitting and to maintaining a good healthy lifestyle [11].

Along with all this, George Flutur, with his fabulous team innovated a chair with a sensor embedded on it, and flags from the microcontroller are being used as the notification to the user. It measures the back features and detect the posture which harms the back of the person. It only focused on the back inclination problem of wrong sitting posture[12].

Hu et al. proposed a Field Programmable Gate Array (FGAP) based smart chair equipped with a two-layer Artificial Neural Network (ANN). They use only flex sensors with Spartan-6 FPGA kit. The proposed work provides a good level of accuracy but the notification mechanism is not up to the mark. Moreover using the FPGA kit and ANN makes it a complex and costly system [13].

Advancement in the field of Machine Learning and Artificial Intelligence has been increasing day by day, with this Muhammad Usman and his partners had done a great job of designing a smart chair using a pressure sensor used for recording the data when a person sits on the chair and getting 10 different trails of humans sitting on the chair and 6 features are been extracted and using the Naïve Bayes and Multilayers preceptor and SVM algorithms for which accuracy stands as 98.75% for two objects, 80% for 3 activities and 98.75% using Naïve Bayes classifier as shown in figure 4 [14].

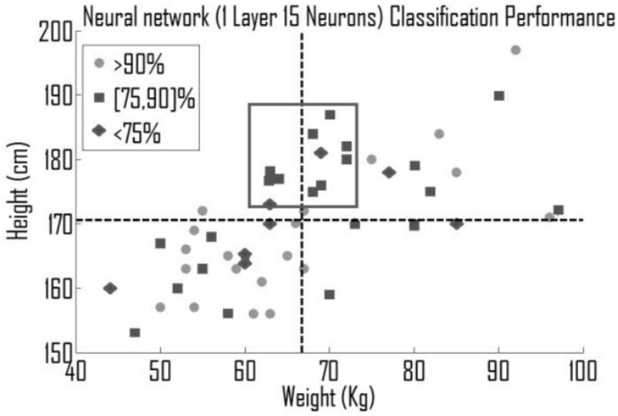

Figure 4: Naïve Bayes's Algorithm output [12]

As discussed in the introduction, during the covid-19 outbreak, everyone was forced to stay away from each other. Mr. Waseem Hussain and two other co-authors had done a great job to make a chair to maintain the social distancing feature which can be added to our project just to follow the guidance given by the government [15]. Also, initially, the smart chair was used to measure the pulse and heartbeat of the customers while they were sitting on a chair, which was innovated by R. Suganya and the other 4 teammates. In addition to that, it monitored the sitting positions using node MCU and Bluetooth 4.0 and a smartphone application was created to accept and detect the information on various seats. This chair using IoT is developed which helps customers to sit in a correct posture [16].

As per the above discussion, many authors have given significant contributions in the field of the smart chair. Based on the above study, this work proposes IoT-enabled smart chair to detect 4 wrong postures with minimum sensors and connected to the cloud. It provides a holistic way of the notification mechanism. Moreover, cloud technology helps to create a database of the seating behavior of a person, which helps to find the root cause of medical problems like spinal injury, problems in leg joints, etc... Section 1 of the paper contains basic need for a smart chair and a literature review. The methodology of the proposed works has been explained in section 2, followed by the result discussion and conclusion in sections 3 and 4 respectively.

II. PROPOSED WORK

In today's world lifestyle of working people is major concern for the healthy life. In the era of automation everything is connected with computer in one or other ways. Physical movement has been reduced at great extent. Almost 80 percent of job time has been spent on chair sitting in front of the computer or at working desk. This invites many physical problems as explain in the introduction section. In a nutshell, sitting posture is uttered most important to avoid this kind of the problem in the future. It is very much important for the person to identify that, he/she sitting in wrong posture and it may cause serious problem to his/her life in longer run. Healthy life style with regular exercise is always the best option, but in reality only few people can adopt it and maintain the regularity. So to notify people about their wrong posture will be second best option to avoid this kind of problems. In a last few years, many authors came up with different idea to notify the person which was discussed in the previous section. As per our limited knowledge, we came to know that there is very few/no attempt made to connect embedded system with cloud technology. With the help of cloud technology, not only we can notify the person about the wrong posture but we can also maintain the database of particular person that can help to identify the actual cause of problem related to spinal or legs.

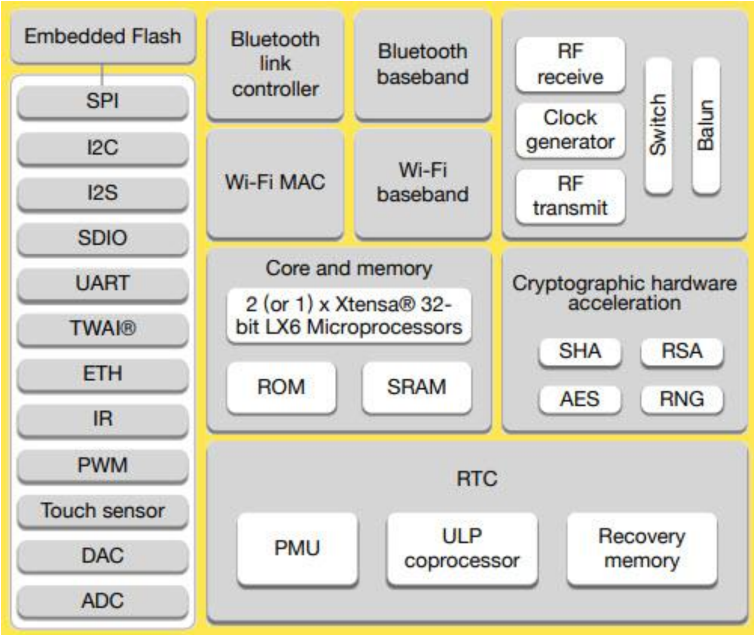

Figure 5: Internal Structure of ESP 32

In a proposed worked embedded system was built around the ESP 32 microcontroller. The ESP32 module support Bluetooth and Wi-Fi combo module. The ESP32 is an integrated dual-core processor chipset with firmware updates, as well as an SDK that facilitates fast on-line programming and has open-source tool chains accessible. This would be advantageous for projects with high performance and ultra-low power consumption. This module can be used for a variety of things, including video streaming, Wi-Fi and Bluetooth-enabled devices, home automation, mesh network apps, and hardware and software engineers who can help build wireless solutions. It is designed to be the ideal module with a single chip capable of 2.4GHz from TSMC ultra low power 40nm technology, to be compact with full functionality of both Bluetooth and Wi-Fi, and to be well optimized for power, RF, robustness, versatility, reliability, application, and profile, with performance to match all category. An internal structure of ESP 32 is given in figure 5 which gives the idea of functional capabilities of ESP 32 board.

The proposed work uses a force sensor and a flex sensor to detect the wrong posture of the person.The A502 force sensor is used where the electrical resistance of the sensor varies with applied force. This force can be pressure, tension, compression, etc…In more general terms it converts this kind of force into an equivalent electrical signal. The working of the force sensor has been explained in figure 10. There are zigzag-shaped electrical conductors bound to polyimide film connected to a metal pad.

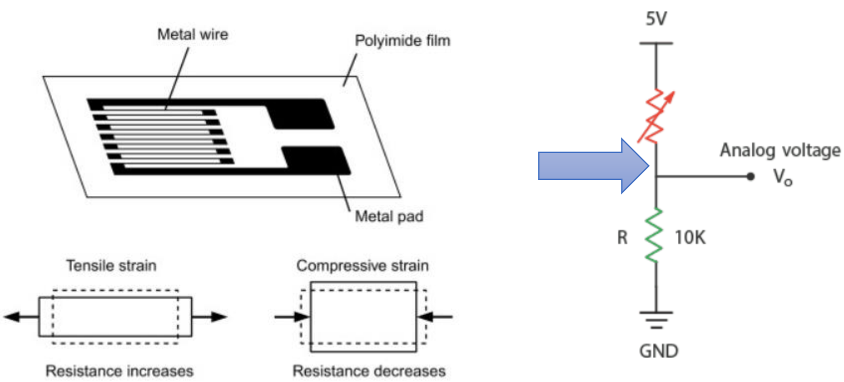

Figure 06: Working of force sensor

When this film is tugged, it stretches and elongates, as do the conductors. When pushed, it contracts and becomes shorter. The resistance in the electrical conductor changes as a result of the form change. The sensor seems to be infinite resistance when there is no pressure (open circuit). The resistance between the two terminals will decrease as you push harder on the sensor's head, but it will return to its original value as you release the pressure. To read the data from the sensor, the sensor output must be connected to the ADC pin of ESP 32 using the pull-down network as shown in figure 06.

Another sensor we used in our work is the flex sensor, which is used to determine the degree of bending. The carbon surface is arranged on a plastic strip as shown in figure 07, which can be turned away to change the sensor's resistance. The bending strip principle is used in this sensor, which implies that as the strip is twisted, the resistance changes. Because the resistance changes when the sensor twists, it works similarly to a variable resistance. With the different degrees of inclination, it gives different resistance as shown in figure 08. By using a voltage divider circuit we convert the change in resistance into equivalent voltage and directly send it to the ADC pin of ESP 32. The complete circuit arrangement is depicted in figure 09.

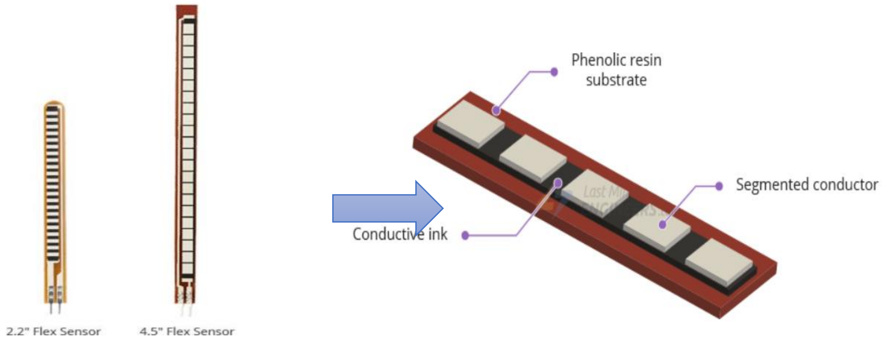

Figure 07: Structure of flex sensor

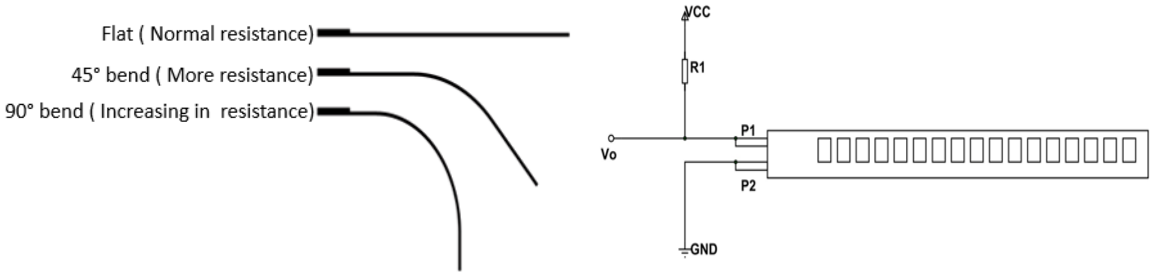

Figure 08: Structure of flex sensor

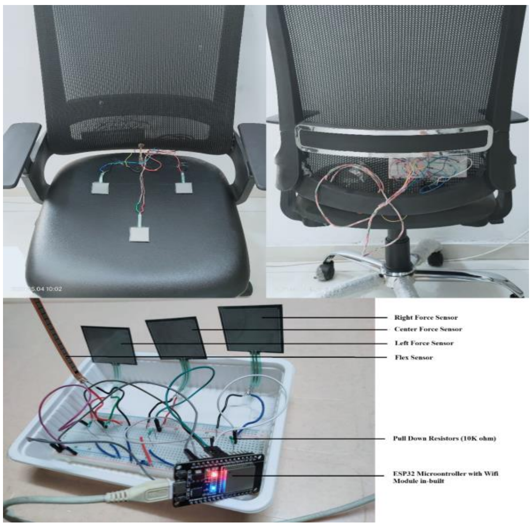

Figure 09: Actual Hardware implementation

The second part of the work deals with cloud technology. Once the data has been fetched by the sensor, the ESP 32 analyzes the data and sends it to the cloud with necessary directives. To complete this IoT part we use the Blynk2.0 platform for cloud connectivity. Blynk 2.0 is much more powerful than the legacy version and cheaper for hobbyists. It maintains the familiar graphical user interface for creating mobile applications and adds a cloud dashboard. It also offers a significantly upgraded ESP and Arduino library packed with features, including support for over-the-air firmware upgrades. The main advantage of using the cloud is that computation and data storage has been done on the server rather than locally on user's device. That helps to reduce power consumption and memory consumption.

The Blynk 2.0 works the MQTT (MQ Telemetry Transport), a lightweight open messaging protocol that allows network clients with limited resources to easily distribute telemetry data in low-bandwidth scenarios. The other advantages of MQTT like quick and efficient execution, low power consumption, less bandwidth usage, and successful in remote sensing and control application makes it suitable for this type of application. Blynk 2.0 web dashboard is depicted in figure 10.

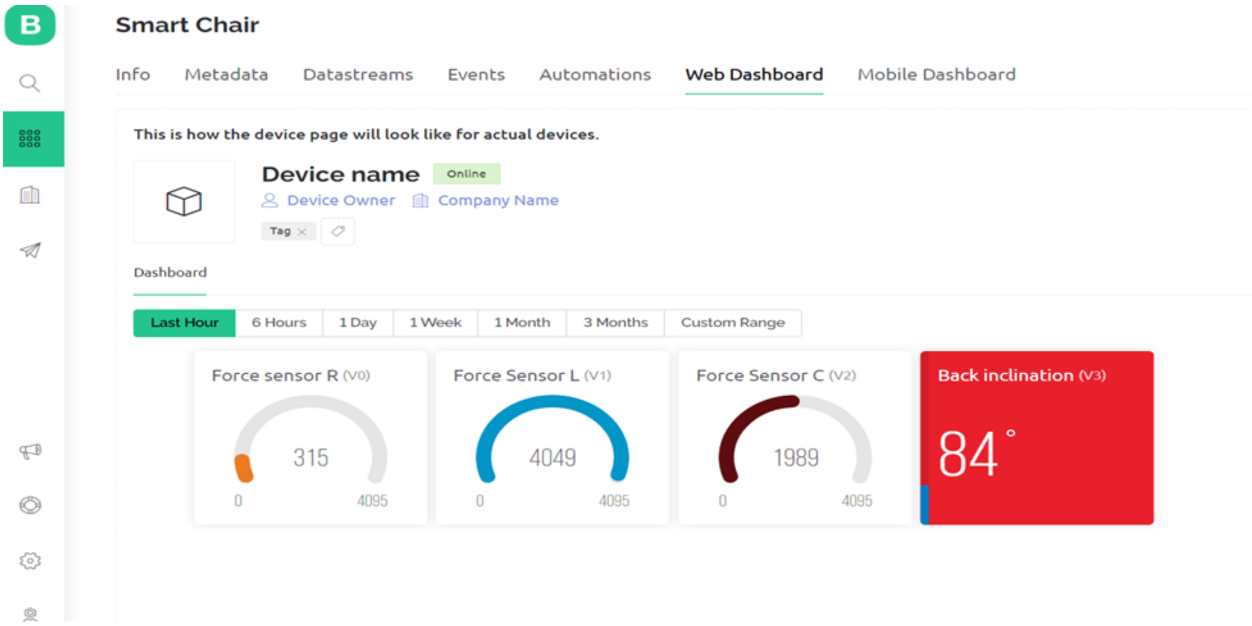

Figure 10: Blynk2.0 dashboard

III. Result Discussion

The entire system's flow diagram has been displayed in figure 15. The entire process starts with the configuration stage where the ESP32 is powered, and the internal configuration stage starts. The ESP32 is powered and start running template code. The Wi-Fi credentials are matched with the template that is been created in web dashboard. It is as shown in figure 11.

Figure 11: Initialization of process

After connecting to Wi-Fi, Decision making and Sensor and Actuators control stage starts, now the ESP32 starts to get the data from the Sensors: Force sensor; flex sensor and working as a bridge, it takes the data and compares the postures condition is matched it or not. It also transfers the data to the Blynk cloud using virtual a pin and the same Cloud work as a publisher and mobile and web dashboards work as a subscriber, and prints the data on the gauge. The sensors have been calibrated with a considerable amount of reading. Based on our reading we have decided on the threshold value for different angles and weights which are given in tables 1 and 2.

Table 1. Calibration of force sensor

Range of Weight (in Kg)	Value of sensor (Average)
40-50	566.5
50-60	745.1
60-70	923.8
70-80	1063.9
80-90	1298.4
90-100	1422.7

Table 2. Calibration of flex sensor

Range of Angle (in degree)	Range of Resistance (in Ohm)
0-10	25000 - 33537.69
11-20	33600 – 42038.89
21-30	42000 - 50000
31-40	51124.48 – 58756.07
41-50	59137.07 – 66945.12
51-60	67478.57 - 70557.46
61-70	71123.24 – 82948.64
71-80	83451 – 91000
81-90	91812.66 - 100000

Blynk offers a very flexible way to send notifications. Users can specify who gets notifications, which events will trigger notifications, and which channel should be used.

Currently, Blynk offers 3 channels to deliver notifications: E-mail, Push notifications, and SMS. The final output of the sensor is displayed as shown in figure 12. The sensor data was also updated on mobile, Web dashboard and also the Notification for the four position mentioned earlier are also got as an alert message and in the mail as shown in figure 13.

```
Force sensor reading = 323 -> light squeeze
Force sensor 2 reading = 317 -> light squeeze
Force sensor 3 reading = 268 -> light squeeze
Force sensor reading = 335 -> light squeeze
Force sensor 2 reading = 333 -> light squeeze
Force sensor 3 reading = 275 -> light squeeze
Force sensor reading = 309 -> light squeeze
Force sensor 2 reading = 304 -> light squeeze
Force sensor 3 reading = 248 -> light squeeze
Force sensor reading = 337 -> light squeeze
Force sensor 2 reading = 332 -> light squeeze
Force sensor 3 reading = 273 -> light squeeze
Force sensor reading = 425 -> light squeeze
Force sensor 2 reading = 418 -> light squeeze
Force sensor 3 reading = 362 -> light squeeze
[6097] <[14|00|04|00|06]vw[00]1[00]0
Force sensor 3 reading = 464 -> light squeeze
[6165] <[14|00|05|00|08]vw[00]2[00]464
Resistance: 58905.29 ohms
Bend: 41.00 degrees
```

Figure 12: Reading of sensor

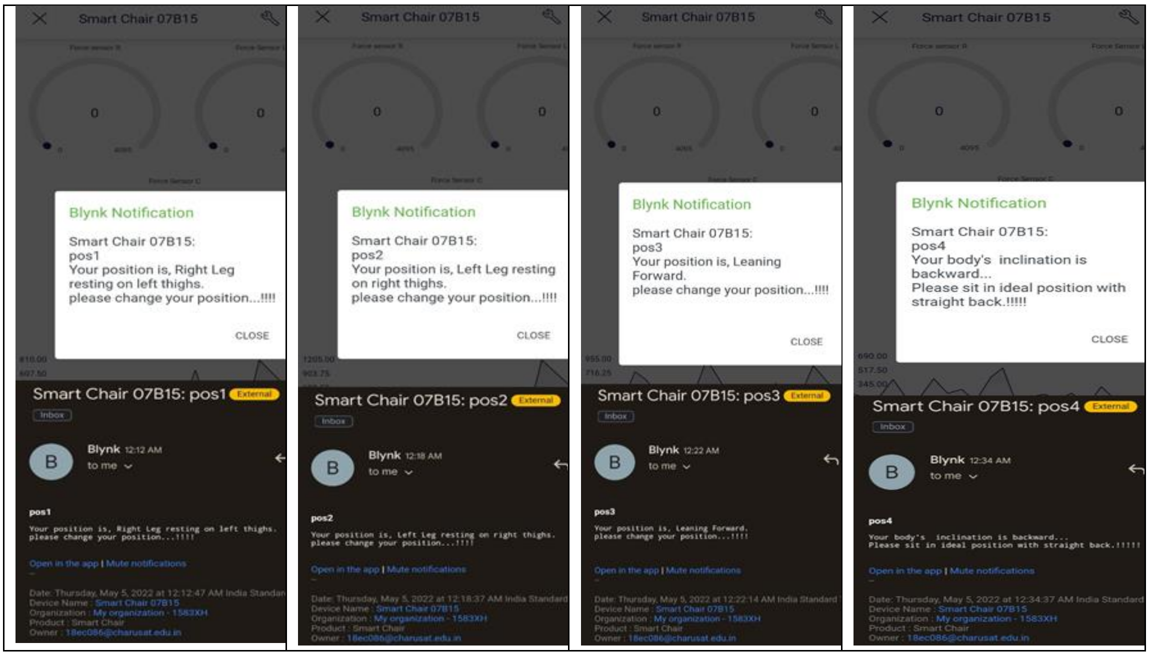

Figure 13: Notification for four positions

As we discussed, many renowned authors have given their valuable contributions to this small field of emerging technology. The previous work helps us a lot to reach this stage. With our limited knowledge, we compared our work with previous work. A detailed comparison is given in table 3. As we can see from the comparison that our proposed work involves almost every aspect of the communication for the notification. It helps to make sure that the user will get aware of his/her wrong posture for sure. Moreover, it also maintains the database of the sitting behavior of the person. This database is quite helpful for the medical field to identify the root cause of the problem.

References	Sensor	IoT	Bluetooth	SMS	Notification by Message	ML and AI	Cloud Computing	Email	Database Creation
[4]	Shape Sensing Array	×	×	×	×	√	×	×	×
[5]	Textile Sensor	×	×	×	×	×	×	×	×
[6]	Pressure Sensor	×	×	×	×	√	×	×	×

[7]	**ECG and BCG Electrode**	√	×	×	×	×	×	×	×
[8]	**Pressure Sensor**	×	√	√	×	×	×	×	√
[9]	**SPO2 Sensor, Heart Rate Sensor**	√	√	√	×	×	×	×	×
[10]	**Actigraph GT3Xþ**	×	×	×	×	√	×	×	×
[11]	**Pressure Sensor**	√	×	×	×	×	×	×	×
[12]	**Capacitive Proximity Transducer**	×	×	×	√	×	×	×	×
[13]	**Flex Sensor**	×	×	×	×	√	×	×	×
[14]	**Pressure Sensor**	×	×	×	×	√	×	×	√
[15]	**IR Sensor**	×	×	×	×	×	×	×	×
[16]	**Pressure Sensor**	√	×	×	×	×	×	×	√
Proposed Work	**Flex Sensor, Pressure Sensor**	√	√	√	√	×	√	√	√

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