

Smart Force Resistive Chair using ML algorithm to foster healthy lifestyle

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In the contemporary professional landscape, extensive periods of sitting have become an intrinsic part of the workforce, particularly pronounced in developing nations. The rise of remote work, accelerated by the COVID-19 pandemic, has further exacerbated sedentary behaviour, causing detrimental health consequences. Prolonged sitting is known to contribute to a multitude of issues, including muscular weakness, weight gain, cardiovascular problems, back pain, and an increased susceptibility to chronic diseases. In this concern, we present a model which detects the posture by collecting force data using eight FRS (force resistive sensors) and running through our custom trained machine learning model which can classify between good and bad postures. The system then gives an vibration alert when incorrect posture is detected. Notably, the posture data is then securely stored in the cloud, facilitating continuous machine learning model enhancement and offering users insights into their posture habits over time. This study introduces a system designed to counteract the adverse impacts of extended sitting by employing force resistive sensors and machine learning algorithms to discern and categorize over twenty distinct postures with an impressive accuracy rate of 98.43%. The emphasis on a cost-effective approach makes this solution accessible and pragmatic for anyone seeking to alleviate the consequences of prolonged sitting, ultimately aiming to diminish muscular strain, enhance spinal alignment, and promote an overall healthier and more active lifestyle.

Keywords: Force resistive sensors, machine learning algorithms, Classification model, diminish muscular strain.

1. Introduction

In developing countries, a significant portion of the workforce is engaged in jobs that require prolonged sitting. Covid-19 pandemic has prompted an increase in remote work for many individuals. Sitting for long hours can have many side effects on one's health and well-being. Many people lead a lifestyle spending maximum time of their day sitting at desks, in front of

computers, or in vehicles. WHO estimates that 3.2 million people die prematurely each year due to a sedentary lifestyle[1]. According to the results obtained from the NMQ (Nordic Musculoskeletal questionnaire), the most prevalent problems among office workers were neck symptoms (53.5%), lower back symptoms (53.2%), and shoulder symptoms (51.6%) [2].

Muscle weakness, weight gain, cardiovascular issues, posture problems, back pain, increased risk of chronic diseases, mental health, blood clot, digestive issues and reduced lifespan are some of the side-effects of prolonged sitting.

Office workers, IT professionals, transportation and logistics professionals, healthcare professionals, academia and research professionals, call centre employees, and financial services professionals sit for longer hours. Sitting for long hours causes lower back pain and upper back pain. Muscle imbalance occurs. The sacroiliac joint and the sacroiliac ligaments are under load. In prolonged slumped posture, the lumbar spine is flexed overtime. Damage includes increase in posterior annulus strain, increase in intradiscal pressure. Flexed postures place stress on the posterior passive tissues [3].

In this context, we introduce the system which can detect the posture by using the force data from the force resistive sensors. We are using machine learning algorithms to detect, analyze and study the posture [5,6,7]. This system can classify more than twenty postures. It also gives a reminder to the user when he or she is sitting in the same posture for a long time. It is advised to change your posture or stand up every twenty to thirty minutes even if you are comfortable. By standing up, the big muscles in the legs contract and relax which results in an increase in certain enzymes which can break up fat in the blood stream[8]. You can just stand up for two to five minutes rather than jog or jump. It helps to burn the calories so that you don't gain much weight. The system reminds you to reset your posture or take a break according to the time[9]. It also gives an analysis report to the user about the posture details daily so that the result can be compared.

2. PROPOSED SYSTEM

The proposed system gives a vibration alert when a user is sitting in the wrong posture for a long time. The main goal of the proposed system is to reduce the effects of prolonged sitting through a cost-effective approach. Maintaining good posture helps in reduced muscular strain, improved spinal alignment, enhanced breathing, decrease When you are sitting and working, it becomes difficult to always remind yourself to stand up or take a break. So, this proposed system activates you to change your posture. This is shown in figure 1.

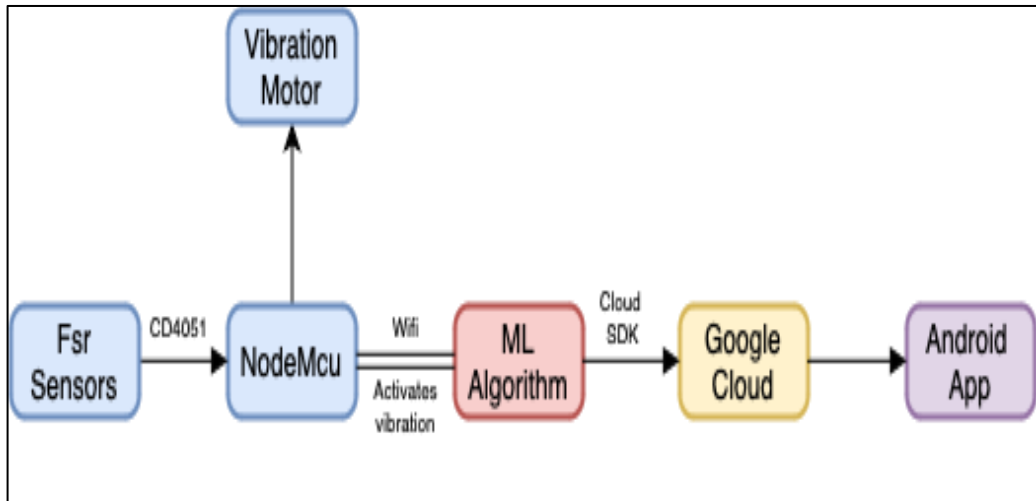


Figure 1: Block diagram of proposed Chair design

3. RELATED WORK

There are many iterations of this in the past where people used deep learning, ultrasonic sensors, force resistive mat etc. but we developed an easy, cost effective and accurate Solution. In addition, we store the human posture behaviour on the cloud and show summary on how the person is doing and how the person improved over the period of time. Our machine learning model can also differentiate over 20 different postures accurately whereas many other implementations just only says whether the person is sitting straight or not. Our system also intelligently notifies the person at regular interval to take a break from sitting by activating vibration motors, with help from local doctors we also assessed best positions to sit on a chair and implemented on that. We documented our entire approach with step-by-step process below. All the past implementations used Ardiuno or Nodemcu with MQTT which is complex and also the data is received slower. In our case we implemented everything on the local WIFI network which is much faster and reliable and cost effective instead on relying on MQTT broker then uploading to cloud then getting the data into python application using API.

4. OVERVIEW OF DESIGN

We are detecting posture by collecting force data from 8 different sensors and running it through a machine-learning model. Which is pre-trained with 20+ postures force data from 8 sensors. To detect force, we are using FSR sensors (force resistive sensors) - it is a type of passive component that changes its electrical resistance in response to applied force or pressure. This data is read by NodeMCU Esp8266- it is a popular and versatile microcontroller development board that's based on the ESP8266 Wi-Fi module as shown in Figure 2. We used it for its low cost, compact size and Wi-Fi connectivity. We need to connect 8 FSRs to ESP8266 using analog ports but ESP8266 has only 1 analog input, hence we are using a Multiplexer (CD4051). It converts 8 inputs into 1 output using 3 digital pins which is used to

select one input at a time using binary values.

Breadboard and jumper cables are used to connect all the sensors and microcontroller. the design of the chair shown in Figure 4

And finally, data from nodemcu is sent to an open Port on the Wifi its connected. We used port number 12345. Our python applications get this data from 12345 port and runs it through a machine learning model which is pretrained with tons of data to detect more than 20 postures. if the data says the posture is incorrect a vibration motor activates on the chair until the position is adjusted. In addition, we stored all this data to analyses the persons daily behavior on the chair and give him a daily report on the posture analysis [10,11]. And improvement from previous days. This data is also used to train our model and keep improving it. We've incorporated a feature that encourages individuals to periodically stand up and take breaks from sitting. This feature utilizes a vibration motor to send alerts in the form of a specific pattern: the motor vibrates for one second, then pauses for one second, and repeats this pattern for a duration of 10 seconds. If a user is occupied and chooses not to stand up during the initial alert, the system will provide another reminder after 30 minutes. This alert cycle continues until the user decides to take a break.

Furthermore, our software allows users to customize the timing and frequency of these alerts, giving them control over how often they receive reminders to stand up and stretch. In Figure 1, the chair has been outfitted with eight force-sensitive resistive sensors (FSRs) – four on the backrest and four on the seat. These sensor placements have been carefully determined through extensive research to optimize their positions for measuring various aspects of the chair's usage [14].

As shown in Figure 3 each FSR comprises two terminals: one is the active terminal, and the other is the common terminal. To power these sensors, the active terminal of each FSR has been connected to the positive power rail on the breadboard. The common terminal of each FSR has been connected to two wires. One of these wires is linked to any one of the available analog ports on the multiplexer. The second wire is connected to a resistor and then to the ground rail. For precise force measurement in accordance with the sensor's characteristic curve, a 10k ohm resistor has been chosen for this specific application.

To provide power and ground for the entire setup, the ground rail and positive rail on the breadboard have been connected respectively to the 'GRD' and '5V' pins on the NodeMCU. Additionally, the NodeMCU has been connected to a battery. The positive terminal of the battery has been linked to the 'VIN' (voltage input) pin on the NodeMCU, while the negative terminal is connected to the 'GND' (ground) pin. This battery setup ensures reliable, portable power for the NodeMCU and the entire sensor array. Finally, to interface the multiplexer with the NodeMCU, the connections have been established.



Figure 4: Intelligent FRS chair

IMPLEMENTATION

Nodemcu is coded using Ardiuno-IDLE, This IDE is used for writing, compiling, and uploading code to Arduino-compatible microcontrollers and development boards. It's a tool for creating and managing Arduino projects. Using “wifi-client” module we connected the nodemcu to Wi-Fi and read the sensors readings [15]. These readings are sent to an open port in our case “12345”. Which then can be easily read by the Python application using socket module. This application detects the motion and then gives nodemcu command to vibrate whenever a wrong posture is detected and also stores the posture data In the cloud and makes posture report.

The Arduino code in mentioned below in supplementary 1:

```

#include <ESP8266WiFi.h>
#include <WiFiClient.h>

const char* ssid = "YourWiFiSSID";
const char* password = "YourWiFiPassword";
const char* serverAddress = "Receiver_IP_Address";
const int serverPort = 12345; // Port to send data to

#define pin_Out_S0 D0
#define pin_Out_S1 D1
#define pin_Out_S2 D2
#define pin_In_Mux1 A0
int Mux1_State[8] = {0};

void setup() {
  pinMode(pin_Out_S0, OUTPUT);
  pinMode(pin_Out_S1, OUTPUT);
  pinMode(pin_Out_S2, OUTPUT);
  Serial.begin(9600);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
}

void loop() {
  updateMux1();

  // Create a CSV string
  String csvData = "";
  for (int i = 0; i < 8; i++) {
    csvData += String(Mux1_State[i]);
    if (i < 7) {
      csvData += ",";
    }
  }

  sendCSVData(csvData);

  delay(5000); // Send data every 5 seconds
}

void sendCSVData(String data) {
  WiFiClient client;
  if (client.connect(serverAddress, serverPort)) {
    client.println(data);
    client.stop();
  }
}

void updateMux1() {
  for (int i = 0; i < 8; i++) {
    digitalWrite(pin_Out_S0, (i & B000000001) ? HIGH : LOW);
    digitalWrite(pin_Out_S1, (i & B000000010) ? HIGH : LOW);
    digitalWrite(pin_Out_S2, (i & B000000100) ? HIGH : LOW);
    Mux1_State[i] = analogRead(pin_In_Mux1);
  }
}

```

Supplementary 1

We developed a machine learning model, using a deep neural network, to process the sensor data and predict the user's posture [12]. The model was trained on the collected dataset and fine-tuned to improve accuracy.

We have used the sequential class from Keras to train the model. Sequential groups a linear stack of layers into a “tf.keras. Model. Sequential” provides training and inference features on this model. In this we used two activation functions() mentioned in supplementary 2 as shown in Figure 5

.tanh

.softmax

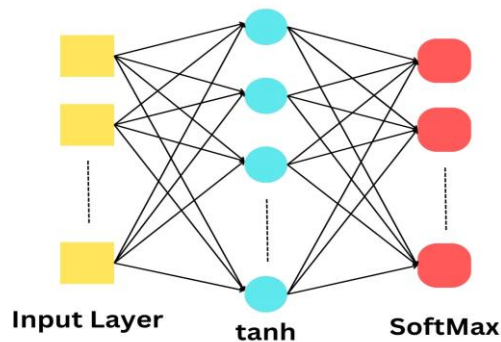


Figure 5: Machine learning model

The tanh function is mainly used to introduce non-linearity, maintain zero-centered outputs and remove any skewness present in the data. Softmax is used to normalize the output of a network to a probability distribution over predicted output classes and to transform raw scores into probability distributions over multiple classes. we also added “sparse_categorical_crossentropy” which is used as a loss function for multi-class classification model where the output label is assigned integer value (0, 1, 2, 3...) which says which position the person is currently in. Then the data received from “12345” port is fed into the machine learning model to predict the output i.e posture.

Simple Machine Reference code as mentioned in Supplementary 2

```
import socket
import numpy as np
import tensorflow as tf
import time
model = tf.keras.models.load_model('model1.keras')
host = "
port = 12345
def main():
    with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as server_socket:
        server_socket.bind((host, port))
        server_socket.listen()
        print(f"Listening on {host}:{port}")

    while True:
        client_socket, client_address = server_socket.accept()
        with client_socket:
            data = client_socket.recv(1024).decode('utf-8').strip()
            print(f"Received data: {data}")
            a=data.split(",")
            for i in range(len(a)):
                a[i]=int(a[i])
            prediction = model.predict([a],1)
            classes_x=np.argmax(prediction,axis=1)
            print(f"Prediction: {classes_x}")

if __name__ == "__main__":
    main()
```

Supplementary 2

Upon analysis of data received from the NodeMCU, a tactile feedback mechanism is activated if an incorrect posture is detected by the integrated machine-learning model [13]. Specifically, a vibration motor embedded within the chair is engaged, providing a gentle but perceptible stimulus to the user. This response is an immediate cue for the individual to adjust their posture and maintain a sound sitting position. This dynamic feedback loop between the user and the chair's sensory system fosters a heightened awareness of posture and facilitates proactive correction, ultimately promoting healthier and more comfortable seated experiences.

All this data is then uploaded to Google Cloud Storage(GCS) by using “GOOGLE CLOUD PYTHON SDK”. First we authenticate the connection Using service account key and then sensor data is uploaded along with time using BLOB module. This data collection and model refinement process form a vital component of this innovative system. Continuously seeking to enhance its accuracy and effectiveness, We then give Graphical reviews on the customer chair behaviours and improvements from their past. This comprehensive dataset is subsequently used to retrain the machine learning model, ensuring its adaptability to evolving user behaviours and postures. By integrating newly acquired data, the model undergoes iterative improvement. This iterative process not only hones the system's performance but also underscores its commitment to remaining attuned to the dynamic nature of the human posture, ultimately culminating in a more responsive and reliable seated experience.+++

```

Listening on:12345
Received data: 353,472,588,1024,1024,1024,1024,1024
1/1 [=====] - 0s 234ms/step
Prediction: [5]
Received data: 1024,950,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 62ms/step
Prediction: [1]
Received data: 1024,1012,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 47ms/step
Prediction: [1]
Received data: 1024,1014,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 47ms/step
Prediction: [1]
Received data: 400,1001,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 31ms/step
Prediction: [5]
Received data: 380,984,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 78ms/step
Prediction: [5]
Received data: 354,934,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 47ms/step
Prediction: [5]
Received data: 1024,1015,1024,1024,1024,1024,1024,1024
1/1 [=====] - 0s 47ms/step
Prediction: [1]
...

```

Supplement 3

To implement the alert system for reminding a person to stand up and take a break using a vibration motor, a separate code is written to the nodemcu using Ardiuno IDLE.

which alerts the person sitting to stand up and take a break from sitting. the alert is a pattern on the vibration motor, that is it vibrates for 1 sec and stops for a sec. and repeats the same for 10 sec. if the user was busy and didn't wanna stand up we would remind again after 30 minutes, this cycle repeats until the user takes a break. The user can change the time period for alerts and the frequency of the alerts from our software.

5. RESULTS

These chairs are designed to provide continuous feedback, helping users improve their posture during various activities such as reading, watching TV, or dining. They are applicable in multiple domains, including ergonomics, healthcare, and workplace efficiency. This technology can be integrated into office furniture, rehabilitation apparatus, and smart home setups to promote enhanced posture and overall wellness. Individuals who prioritize their posture and overall well-being can incorporate posture prediction chairs into their home environments. Educational institutions like schools and universities can introduce these chairs to classrooms to motivate students to maintain proper posture while studying. With gentle reminders and feedback, these chairs can assist students in sitting with correct alignment, reducing fatigue and discomfort during extended lectures or study sessions as shown in Supplement 3

Posture prediction chairs can serve as tools to encourage improved sitting habits among employees in office settings. In an era of remote work, individuals working from home can benefit from these chairs to maintain good posture during extended periods of computer-based work as shown in Figure 6

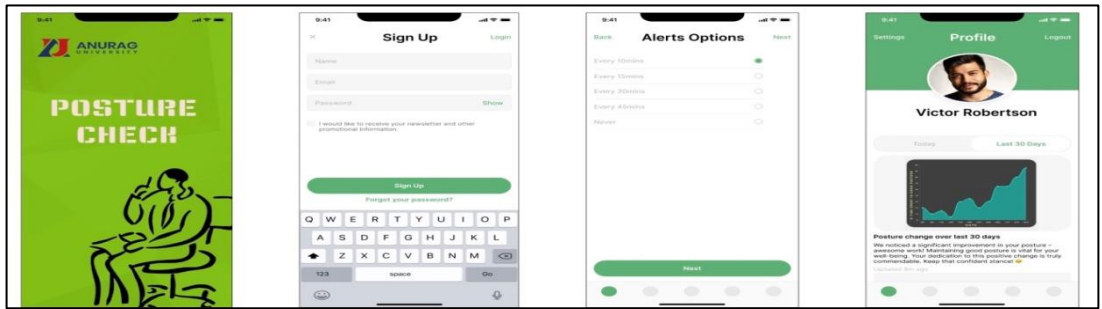


Figure 6: App Design

6. CONCLUSION

Our system enhances individuals' health awareness by providing continuous updates, helping them proactively address unnoticed health deterioration. It also aids in preventing the adverse effects of prolonged sitting. Our system primarily benefits individuals who work long hours

and maintain improper or static postures. It offers users a comprehensive analysis report to aid in self-improvement and includes reminders to stand or take breaks for enhanced well-being. This proposed system activates the users by sending vibration alerts. This system also classifies the postures and monitors to reset the posture if needed. Our system would maintain one's health in their stressful and packed schedule. By enabling users to set and track personalized health goals, it transforms into a steadfast companion committed to maintaining well-being within demanding schedules.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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