iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VI Month of publication: June 2023

DOI: https://doi.org/10.22214/ijraset.2023.53721

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VI Jun 2023- Available at www.ijraset.com

IOT Based Smart Chair to Help with Back Pain

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Abstract: This Poor sitting posture is a common cause of low back pain, as it places excessive pressure on muscles and discs. To address this issue, smart office chairs have been developed using IoT, wireless communication, sensing, and intelligent control technologies. This paper proposes and implements a system for detecting incorrect sitting positions using a smart chair equipped with two tactile pressure sensor mats, vibration actuators, NodeMCU , a data acquisition module, and a cloud server. The system notifies users of incorrect sitting positions through visual and vibration feedback, which is received through a mobile application. Simple rules were defined to process sensor data to recognize wrong sitting postures, and the data collected from smart chairs were stored in a MongoDB database using a private cloud solution from QNAP. The Node-RED application was proposed for the entire logic implementation.

I. INTRODUCTION

Maintaining proper posture while sitting for prolonged periods is important for preventing back problems and promoting overall health. However, many individuals are not fully aware of the different features and adjustments available on their office chairs and do not use them in an optimal ergonomic way. Moreover, people often adopt incorrect postures without realizing it, which can lead to chronic pain and discomfort.

To address these issues, smart chairs have been developed with the capability to provide feedback on posture through vibrotactile and visual means. There are different methods for monitoring posture, including computer image processing, wearable sensors, and load distribution measurement. However, each approach has its own advantages and limitations.

Our team conducted a review on patient monitoring using computer image processing, which involves analysing video signals to detect posture. However, this method has limitations related to camera distance and the need for reflective markers on the body. To overcome these limitations, we developed a video system that monitors posture by placing reflective markers on the head, neck, and spine.

Wearable sensors offer several advantages over image-based systems, including portability and angle independence. Wearable sensors can be attached to clothing or directly placed on the skin, making them less obtrusive than other types of sensors.

In this paper, we present a complete system concept for smart chairs that provides feedback on posture and promotes proper ergonomic usage. We focus on the microcontroller hardware solution implemented in the chair and the communication between the microcontroller and server. Our primary goal is to design a system that is easy to implement in any office space and does not require the use of the same smart chair every day.

The server-side of the system is based on the QIoT Suite cloud solution, which includes MQTT gateways, Node-RED application, and MongoDB database. The system collects data from the smart chairs and stores it in the database, allowing users to track their posture over time. The Node-RED application is used for the logic implementation of the system, which processes the sensor data and provides feedback to the user in real-time.

Overall, the proposed system can help promote proper posture and prevent chronic back problems, which are becoming increasingly common due to the sedentary nature of modern work environments

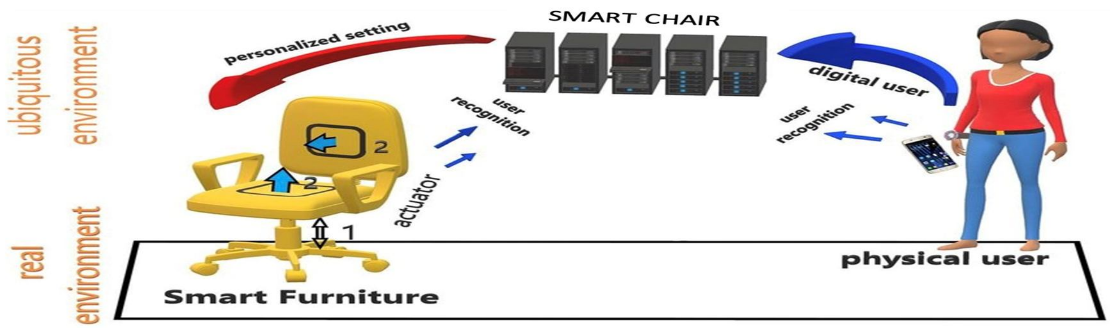

Figure 1: The system concept proposal

Figure 1 illustrates the proposal of the system concept. The overall system consists of a variable
Each smart chair has NodeMCU, external battery power source, vibration actuators, and two tactile pressure sensor mats, the network-attached storage from QNAP holds the cloud solution. It features the Message Queuing Telemetry Transport (MQTT) broker for communication, Node-RED for the logic, and Mongo database for data storage. In summary, our research is to reduce sedentary chair users' risk of developing health problems by providing effective visual feedback about adjusting sitting behaviour.

II. METHODOLOGY

A prototype of our proposed smart chair is constituted by an ergonomic office chair, a data acquisition model consisting of NodeMCU microcontroller, tactile pressure sensors, computational terminal and vibration actuators. For our smart chair prototype specifically, pressure sensor mats will be placed one on the seat surface and one on the backrest, respectively. Made of stainless-steel microfibers, polyester, cotton, and polyethylene tissue, these tactile pressure sensor mats will be adopted to monitor users' sitting patterns. Each sensor mat looks like a soft fabric piece with high flexibility and extensibility without sacrificing user experience. Conducting fibers in the fabric allows measuring pressure distribution on uneven surfaces, data acquisition module holds NodeMCU microcontroller which will be used to collect signals from sensors and communicate with vibration actuators and store the data in the cloud server, to send it to mobile App wirelessly.

Figure 2: Common sitting positions

A few major aspects will be used to determine a correct sitting posture, such as keeping both feet flat on the floor, positioning knees at the same height as the hips, and keeping the lower back against the chair. For example, two parts of the body contacting the chair-the pelvis with the upper shanks and the back is considered as a proper sitting. Accordingly, the most common 6 sitting postures found in office environments will be adopted to collect pressure data: (P1) seated upright, (P2) leaning back, (P3) leaning forward, (P4)slouching , (P5) leaning side, (P6) crossed leg. To collect pressure data from sensor mats and provide the smart chair with processing and delivering capabilities,NodeMCU is used.

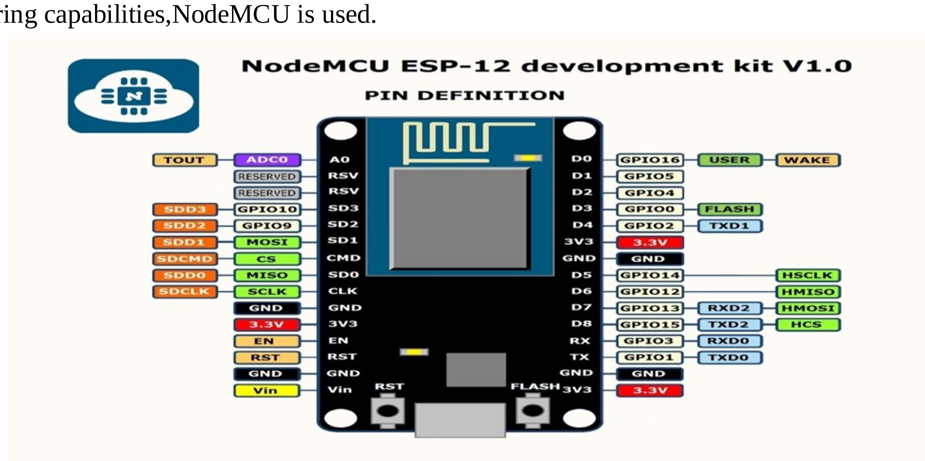

Figure 3: hardware schematic with NodeMCU

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Figure 3 shows the NodeMCU flowchart diagram. The start begins with the definition of variables and their initialization. The most important variables are the WIFI network name (SSID), WIFI password, cloud server IP address, and MQTT credentials. Then the data collecting pins, serial, and WiFi communication are initializing. The first thing that the program does is connecting to the WiFi network. If the initial login fails, the system waits for 5 seconds and then retries the operation until the successful login.

The central unit of our smart system is the NAS from QNAP . This unit runs all programs and cloud services that provide connectivity, chairs management, data storage, and data evaluation.There are two primary services: QIoT Suite. MongoDB .The QIoT Suite is an application, which could be installed directly from the application center on NAS. QIoT Suite integrates different services, which are necessary to provide a complex solution in the IoT world, into one application. It includes the MQTT broker, Node-RED, and Freeboard and supports multiple protocols and dashboards. MongoDB is a popular, general-purpose, document based, distributed database, which is common in a cloud solution and IoT world. All data are stored in MongoDB for further evaluation. Figure 4 shows the flowchart of the system functionalities.

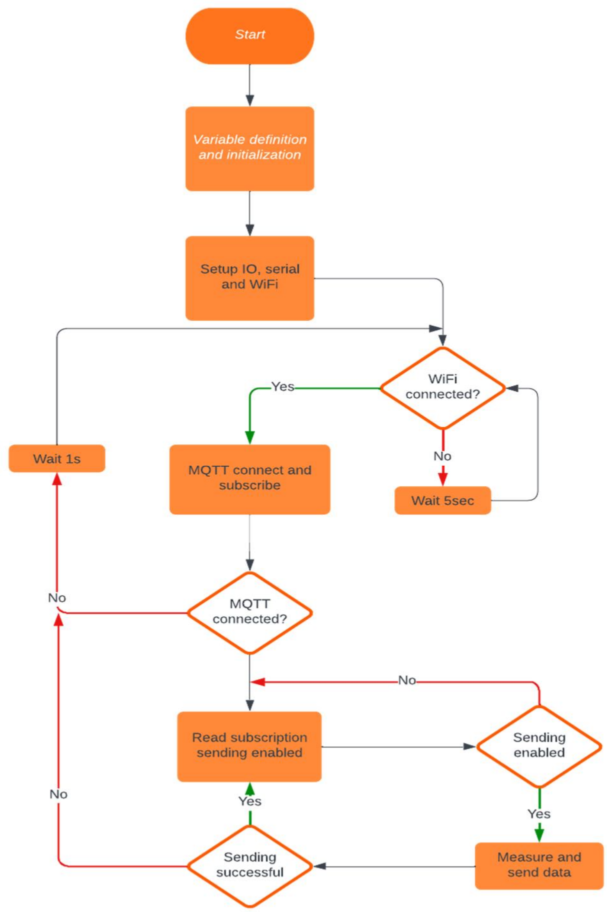

Figure 4: NodeMCU source code flowchart

The next step is building a connection with the NodeMCU. It connects to the MQTT broker using predefined credentials. The MQTT protocol communication is provided by an external library Adafruit MQTT Library. To build the MQTT connection, we require the client instance of the class Adafruit_MQTT_Client. This client connects to the MQTT broker. We have to create an additional object for receiving the responses from the broker. The instance of the class Adafruit_MQTT_Subscribe provides such an interface. For sending data, we need an instance of a class Adafruit_MQTT_Publish. The consequence loop checks if the MQTTconnection is still live. If the connection is active, the pointer to the object from class Adafruit_MQTT_Subscribe is created for fetching the new data on the subscribed channel. The channel identifier for reading commands, reads CHAIR_ID,where it is the smart chair identification number. On the cloud side, the MQTT broker sends the chair command using this channel. When the user connects to the smart chair using

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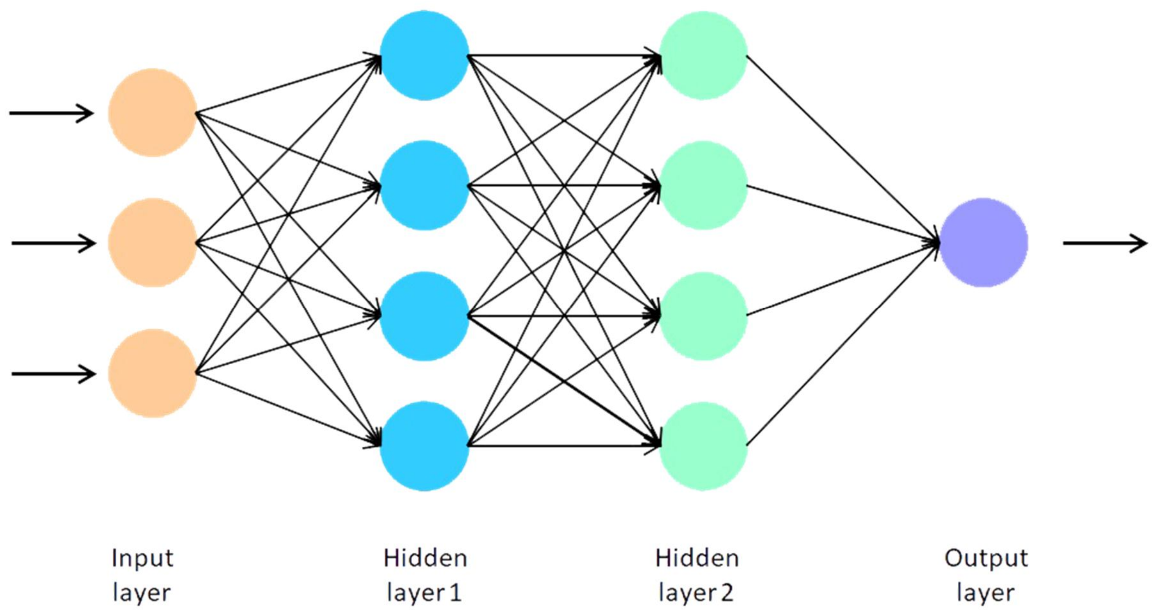

Figure 5: ANN neural network

a smart mobile application, every time the start command is issued on this channel and the NodeMCU being used by the data acquisition module starts reading sensor data each time and then data acquisition module which is holding this NodeMCU pre-processes data and implements ANN by using TensorFlow in python to obtain classified posture and it is given to posture classification, as well as the chair's vibrartion actuators to produce the immediate feedback of his bad posture,NodeMCU will now send the visuals to cloud server, this continues in regular intervals till user logs out, the stop command is then issued from the broker. Afterwards, the string in JavaScript Object Notation (JSON) format is prepared and published to the broker using Ada-fruit_MQTT_Publish object,the data are published. If there are no active measurements incoming in time, we need to send a periodical ping command to keep the connection with MQTT alive. Without this ping, a link would break down after some time if no communication took place.

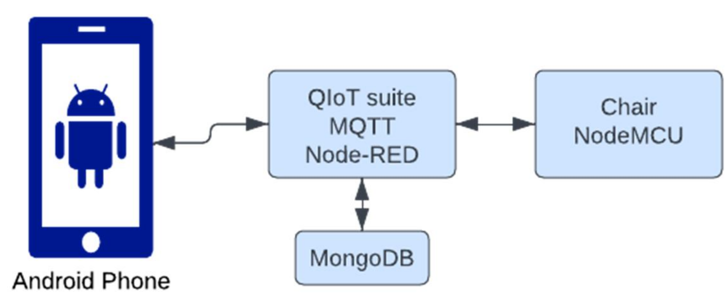

Figure 6: The system communication chain.

The central unit of our smart system is the NAS from QNAP ,this unit runs all programs and cloud services that provide connectivity, chairs management, data storage, and data evaluation. there are two primary services: QIoT Suite. MongoDB ,the QIoT Suite is an application, which could be installed directly from the application center on NAS. QIoT Suite integrates different services, which are necessary to provide a complex solution in the IoT world, into one application. It includes the MQTT broker, Node-RED, and Freeboard and supports multiple protocols and dashboards. MongoDB is a popular, general-purpose, document based, distributed database, which is common in a cloud solution and IoT world.

All visuals are stored in MongoDB for further evaluation. Figure 4 shows the flowchart of the system functionalities, the smartphone application also uses the MQTT protocol to communicate with the QIoT Suite server, the communication is processed via the Node-RED application. Both sides are using the MQTT communication protocol to exchange messages with the QIoT. NodeMCU sends the visual data to the cloud. Data are processed via Node-RED, stored into MongoDB, and then sent to the mobile application, it then stores his visual feedback in the app with his credentials(user login, password, and chair identification number). The data from multiple chairs are stored on one server, the successful connection to the MQTT server is followed by automatic login to the selected smart chair.

III. CONCLUSION

A smart chair prototype with pressure mats in the seat pad and backrest will be developed to detect the posture and provide vibrotactile and visual feedback to users. This project will find out how to facilitate office chair users to adjust their sitting behaviour by providing synchronous vibrotactile feedback and actionable visual feedback. The huge potential value and impact is to reduce sedentary chair users' risk of developing health problems by providing effective visual feedback about adjusting sitting behaviour. The user can see the information about sitting posture correctness and other pieces of detailed information in the mobile application. Our goal was to create simple rules to detect correct sitting posture in the term of minimal computation power requirements.

IV. ACKNOWLEDGEMENT

We want to express our deep-felt gratitude and sincere thanks to our guide Mrs. Shilpa Shesham, Assistant Professor, Department of Al, Anurag University, for her skillful guidance, timely suggestions, and encouragement in completing this project. We want to express our profound gratitude to all for having helped us in achieving this dissertation. Finally, we would like to express our heartfelt thanks to our parents, who were very financially and mentally supportive and for their encouragement to achieve our goals.

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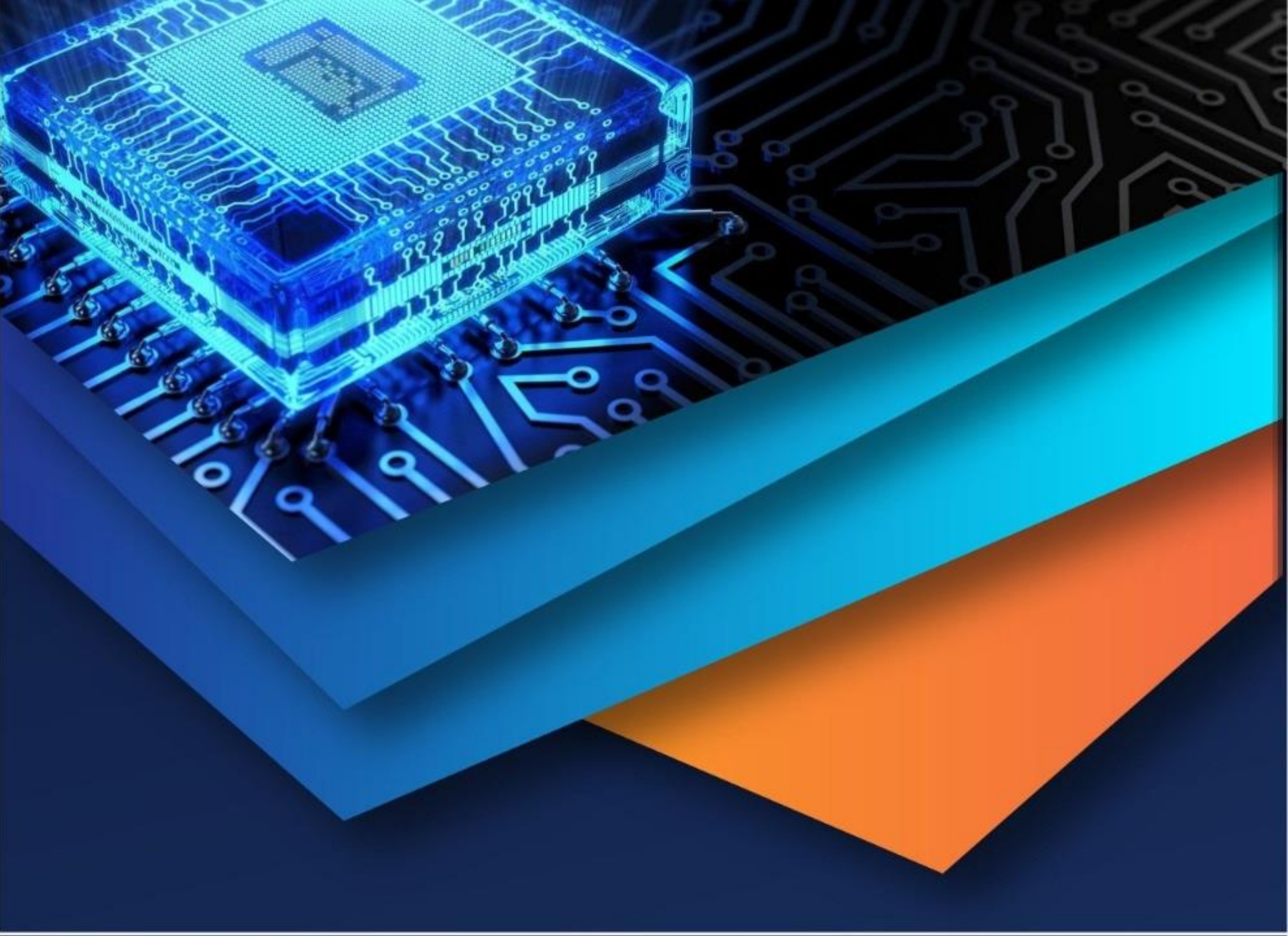

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