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Original Article

AHAS: Autonomous Height Adjustment System for Smart Office Chair

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Abstract *- The quality of human life is an important aspect that must be considered. Sitting is one of the activities humans routinely carry out, which causes several health risks if not done correctly for a long time. Several studies have been conducted regarding the upper limb sitting position, but little has been discussed about the lower limb. Therefore, this paper presents the Autonomous Height Adjustment System (AHAS) for Internet of Things (IoT)-based Smart Office Chairs. This study focuses on adjusting the height of office chairs based on the user's body weight. Modifications need to be made to standard office chairs by adding load cell sensors and linear motors as actuators. The main unit microcontroller reads data from sensors and actuator controllers based on the proposed algorithm. The data obtained is then stored on a cloud server using the IoT concept with the HTTP protocol to monitor it in real-time. Several phases were carried out, from the mechanical, electrical, and software design stages, subject selection, and data acquisition to the implementation stage. The results presented show that the proposed system can work well and be a solution for autonomous seat height adjustment. A low-cost IoT-based prototype Autonomous Height Adjustment System for smart office chairs has been successfully developed and presented in this paper.*

Keywords – *Smart chair, Height adjustment, Autonomous, Office chair, Internet of Things.*

1. Introduction

The Internet of Things (IoT) is the key to the current digital revolution; this can certainly improve the quality of life and work to provide many benefits for humans [1]–[4]. Several objects can automatically exchange data with IoT over the network/cloud without human intervention. With this technology, simple things can play a significant role in human daily life [5,7,27]. The medical field is essential in supporting human quality of life, and IoT can provide convenience in conducting remote monitoring[8]–[10].

The Covid pandemic has begun to subside, and office work and offline learning have started to be implemented again; these two things are closely related to long-sitting activities. Sitting is one of the factors causing chronic disease/spinal disorders, causing low back pain and movement dysfunction. Specifically, low back pain occurs in almost every adult globally. Several studies have shown that the source of their low back pain is the wrong posture when sitting at work [11], [12]. This also has a negative impact on the company, where employee productivity decreases and requires medical treatment [28]. Limited physical activity of employees at work or school due to extended sessions or overtime. Approximately half of the day is spent by employees in front of the computer, thereby increasing the number of diseases related to musculoskeletal[14]. Therefore, a solution is required in the form of a smart chair capable of functioning autonomously.

Several studies on smart chairs have been carried out to overcome some of the problems of human posture when sitting in a chair. Various sensors are used and installed on parts of office chairs. The application of IoT technology and data collection process methods has been carried out, as shown in Table 1. The research that has been developed focuses on the upper limb sitting posture of the human body. Therefore, this research, carried out in preliminary studies, has developed an Autonomous Height Adjustment System (AHAS) specifically focusing on optimizing the lower limb sitting posture for office chairs. This research has effectively implemented mechanical, electronic, and IoT-based monitoring software interfaces to address the automatic seat height adjustment challenge in its initial stage. This research further advances Cloud Real-time Database Recording (CRDR) development by establishing an HTTP protocol connection between the microcontroller and the MySQL cloud database. This update represents a notable improvement compared to previous research. The next sections of the paper are structured as follows: first, the material and methods are described in Section II, along with the core concepts. Section III describes the experimental results and discussion, while Section IV provides a conclusion.

Table 1. Related works for smart chair

References	Targeted Domain	IoT	Sensors	CRDR	Place
[15]	Sitting posture (Upper Limb)	X	Fiber Optic Curvature Sensor (Seat Pad)	X	Canada
[16]	Sitting posture (Upper Limb)	X	Textile Pressure Sensor (Seat Pad)	X	Switzerland
[17]	Sitting posture (Upper Limb)	X	Pressure Sensor (under each of the chair legs)	X	Germany
[18]	Sitting posture (Upper Limb)	✓	ECG and BCG Electrode (Backrest, Seat Pad)	X	Korea
[19]	Sitting posture (Upper Limb)	X	Pressure Sensor (on Seat Pad)	✓	Korea
[20]	Health Monitoring	✓	SPO2, Heart Rate, and Load Cell (Chair Arm Pad, Human Arm, and Underneath Human Feet)	X	India
[21]	Monitor Sitting Behaviour	X	BMA Axia Smart Chair (Seat Pad, Backrest)	X	Netherlands
[22]	Student Attendance and Monitoring	✓	RFID, Load Cell, and Temperature, MEMS Sensor	X	India
[23]	Sitting posture (Upper Limb)	X	Capacitive Proximity Transducer (Seat Pad, Human Back)	X	Romania
[24]	Sitting posture (Upper Limb)	X	Flex Sensor (Backrest, Seat Pad, and Arm Pads)	X	Mexico
[25]	Sitting Posture (Upper Limb)	X	Pressure Sensor (Backrest, Seat Pad)	✓	Pakistan
Proposed AHAS	Sitting Posture (Lower Limb)	✓	Pressure Sensor (Seat Pad)	✓	Thailand

2. Materials and Methods

2.1. AHAS Office Chair Design

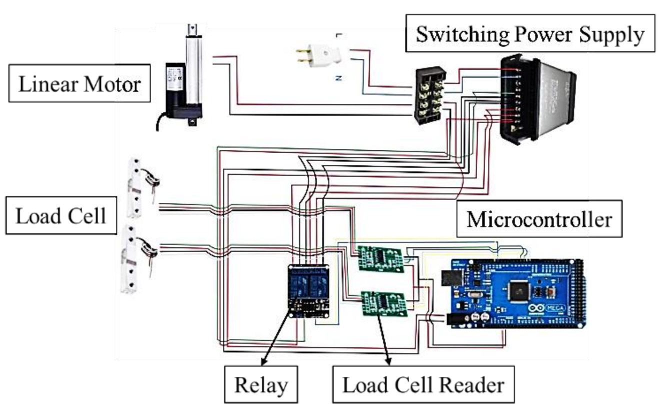


Fig. 1 Electronics wiring diagram

The flow of the electric circuit from the automation system is shown in Figure 1. The AHAS for this office chair uses two modified 30 kg load cell sensors with the addition of an acrylic platform. These two sensors are input from the system connected to the microcontroller unit (Arduino Mega2560) via a Load Cell reader. Based on the sensor readings, the microcontroller will give a signal to the relay to control the switching power supply to regulate the movement of the Linear Motor. Figure 2 shows the mechanical structure of the Load Cell sensor installation. The components used in this study are low-cost technologies easily duplicated and utilized by the wider community.

2.2. Proposed AHAS Algorithm

Based on the system overview flowchart shown in Figure 2, the system works based on input from the two load cell sensors. The results from the first and second load cell sensor readings are then added and processed based on the proposed categorization logic. The weight category was obtained from previous manual measurement trials on several human subjects. The linear movement of the motor is based on this categorization, and the duration of the motor movement is run to set the Auto Height Adjustment System.

Figure 4 shows the structure of the load cell sensor installation where the sensor position is in the middle between the two top and bottom acrylic plates. Spacers are installed to connect the acrylic layer and the load cell. Base feet are installed at the base to support the four bottom acrylic corners. The load cell sensor used adopts the Strain Gauge and Wheatstone Bridge [26] principles based on Figure 3 and equation (1) where V_{in} is the input voltage whose value is constant while V_{out} is the output voltage whose value depends on the balance of each resistor (R_1, R_2, R_3, R_4). In equation (2), if the value of each resistor is balanced, then the V_{out} value is zero.

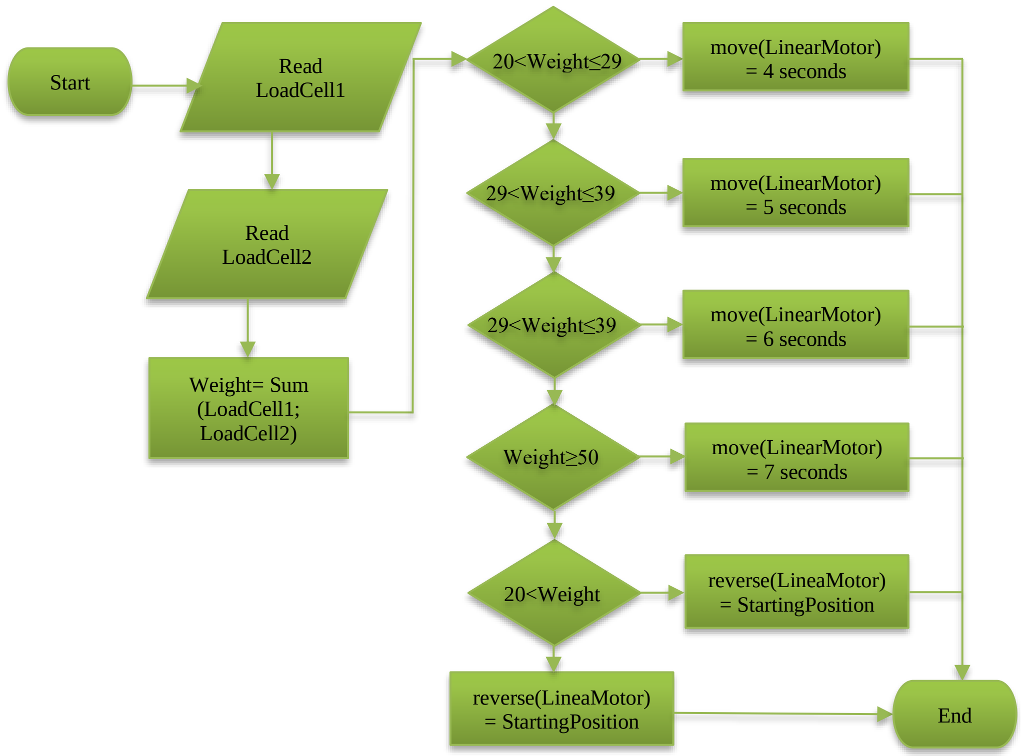


Fig. 2 AHAS overview flowchart

$$V_{out} = \left(\frac{R_3}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}\right) V_{in} \tag{1}$$

$$\frac{R_1}{R_2} = \frac{R_4}{R_3} \tag{2}$$

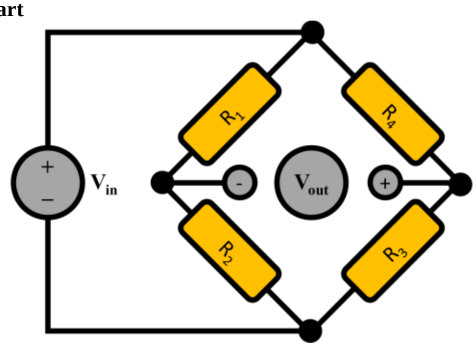


Fig. 3 Wheatstone bridge

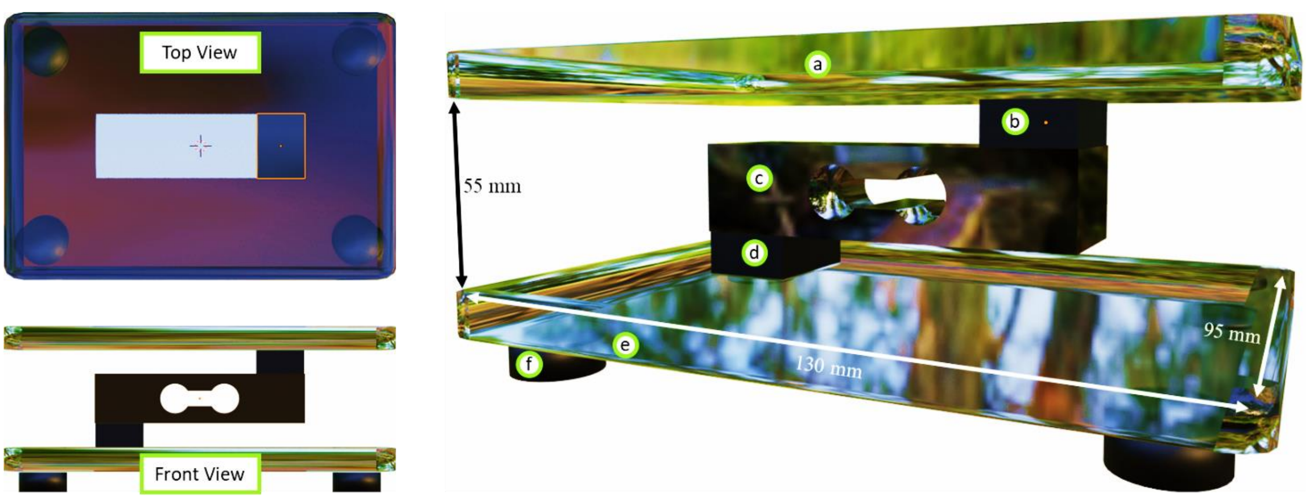


Fig. 4 Load Cell Mechanical Design. (a) Top Acrylic Platform. (b) Top Load Cell Holder. (c) Load Cell Sensor. (d) Base Load Cell Holder. (e) Base Acrylic Platform. (f) Base Feet.

2.3. Subjects

In the initial phase, data was gathered from multiple individuals while they interacted with objects to determine their weight category. The study involved 6 participants (four men and two women), aged between 12-34 years, with weights ranging from 29-65 kg. In the second stage (testing), all participants come from the same institution but with different jobs. The subjects used in this study consisted of 3 lecturers, two office staff, and 16 students randomly recruited and willing to do data recording. The test location was carried out at the Mechatronics Engineering Laboratory, RMUTT. This research does not involve medical aspects under the law. Before the experiment, the participants were informed about the experiment's objectives and goals. They provided voluntary consent to participate in the study.

2.4. Data Acquisition

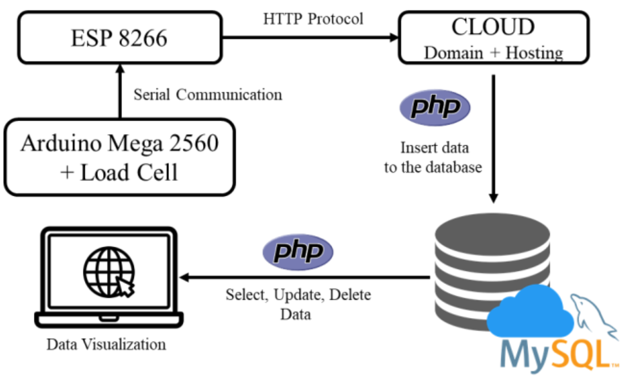


Fig. 5 Data acquisition using HTTP protocol and MySQL

The data acquisition process from the MCU (Arduino Mega 2560) is carried out using IoT technology, with serial communication as the nodeMCU data bridge (ESP8266). The HTTP protocol is used as a link between nodeMCU (ESP8266) and the cloud server. Services placed on the cloud will execute commands in the PHP language to store data in real-time on the MySQL database. The libraries used in this study are ESP8266WebServer.h and ESP8266HTTPClient.h.

The collected data can then be monitored on a computer/laptop/smartphone using a browser application (Figure 5). The data acquisition procedure was carried out by inviting the subject to sit sequentially and then recording the subject's weight, time, seat height, and the current used by the linear motor.

3. Experimental Results and Discussion

From the wiring diagram that has been designed, the electronic components are assembled, as shown in Figure 6. Furthermore, the controller box is installed on a modified office chair, as shown in Figure 7.

The modification is carried out by replacing the five caster wheels with a fixed stainless-steel stand; this is done to get a stable base as a preliminary study. The load cell sensor is placed in the middle of the seat pad, while the linear motor is placed between the chair base and the seat pad. Figure 8 shows the process of mechanical modification of the original office wheelchair.

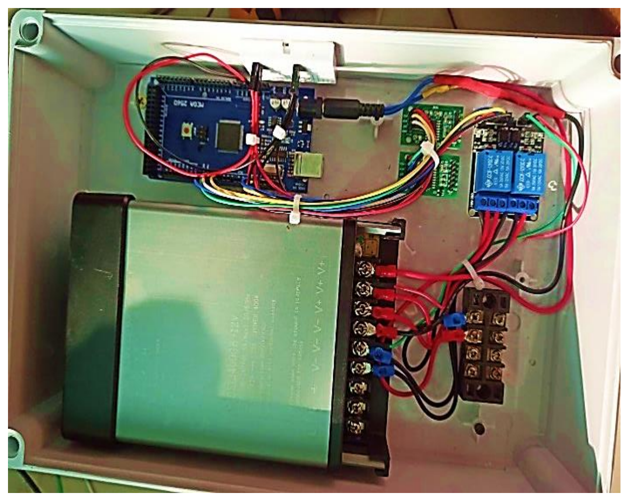


Fig. 6 AHAS control box

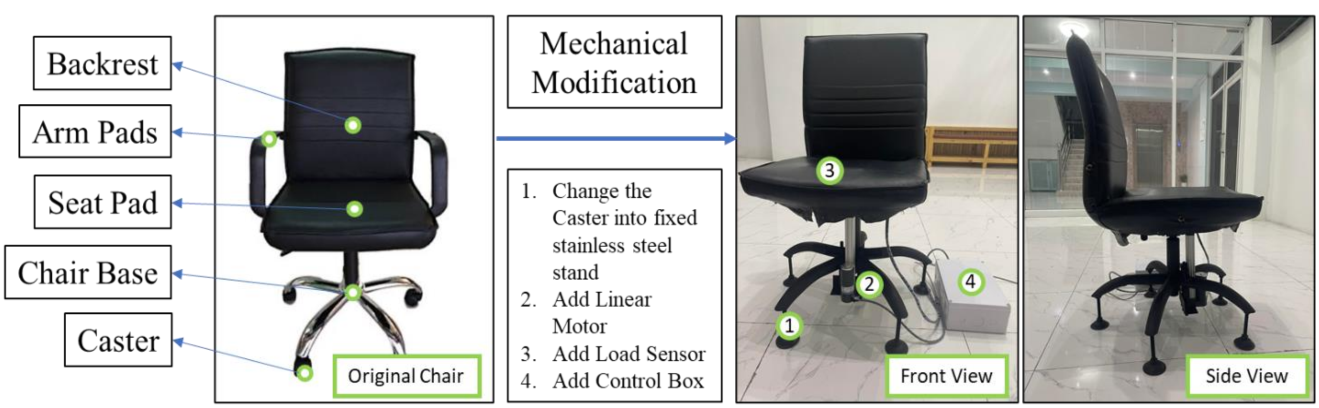


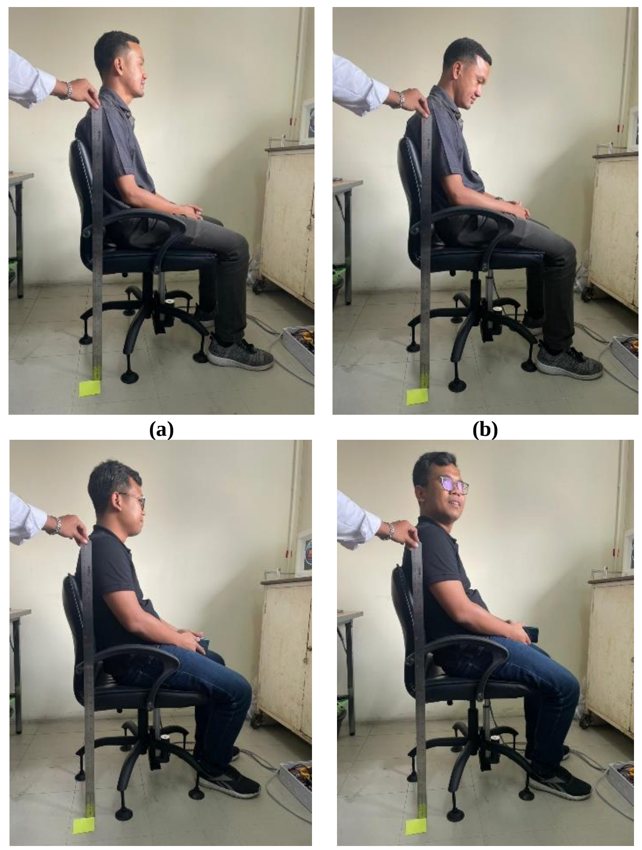
Fig. 7 Mechanical and electrical modification from original office chair

(a) (b) (c) (d)

Fig. 8 Modification Process of Original Office Chair. (a) Change Caster into Fixed Stand. (b) Linear Motor Deployment. (c) Original Seating Pad. (d) Load Call Deployment into Seating Pad

Table 2. Data collected from 21 subjects

Testing of AHAS				
Subjects	**Chair Height (cm)**	**Time (s)**	**Subject's weight (kg)**	**Current at Linear Motor (amp)**
S1	6.5	7.32	65	0.24
S2	5.7	6.29	67	0.25
S3	6.8	7.7	96	0.4
S4	4.6	5.19	47	0.18
S5	5.4	7.3	60	0.25
S6	6.9	6.35	70	0.29
S7	5.2	5	50	0.2
S8	6.8	6.25	62	0.24
S9	5.9	7.34	58	0.23
S10	4.4	5.1	48	0.19
S11	6.6	7.34	91	0.39
S12	5.2	6.16	47	0.18
S13	5.7	5	52	0.21
S14	6.1	6.13	67	0.25
S15	5.7	6.77	62	0.23
S16	6.2	7.22	60	0.25
S17	6.8	7.18	70	0.26
S18	5.8	6.43	73	0.33
S19	5.6	6.19	55	0.21
S20	5.5	5.59	50	0.2
S21	5.4	6.19	70	0.26



(c) (d)

Fig. 9 Data Acquisition Process. (a) S8 before adjustment. (b) S8 after auto adjustment. (c) S21 before adjustment. (d) S21 after auto adjustment.

The results of this study on twenty-one subjects are presented in Table 2, showing that the current use in each trial is not much different. The lowest current of 0.12amp occurs in subjects 4 and 12, weighing 47kg. At the same time, the most significant current of 0.4amp occurs in subject 3, with a weight of 96kg. Figure 9 shows the process of measuring and recording research data. Figure 8 (a) and (c) are the initial positions, while (b) and (d) are the results of the auto adjustments made by the system. The data was visualized in graphical form, as depicted in Figures 10 and 11. Figure 10 shows the relationship between subject weight, motor linear motion time and seat height for each subject.

The heavier the subject received, the height of the chair will also increase along with the logic embedded in the MCU using the delay of the motor's linear movement as a reference. Whereas in Figure 11, it can be seen that the current consumed by the linear motor increases with the subject's weight.

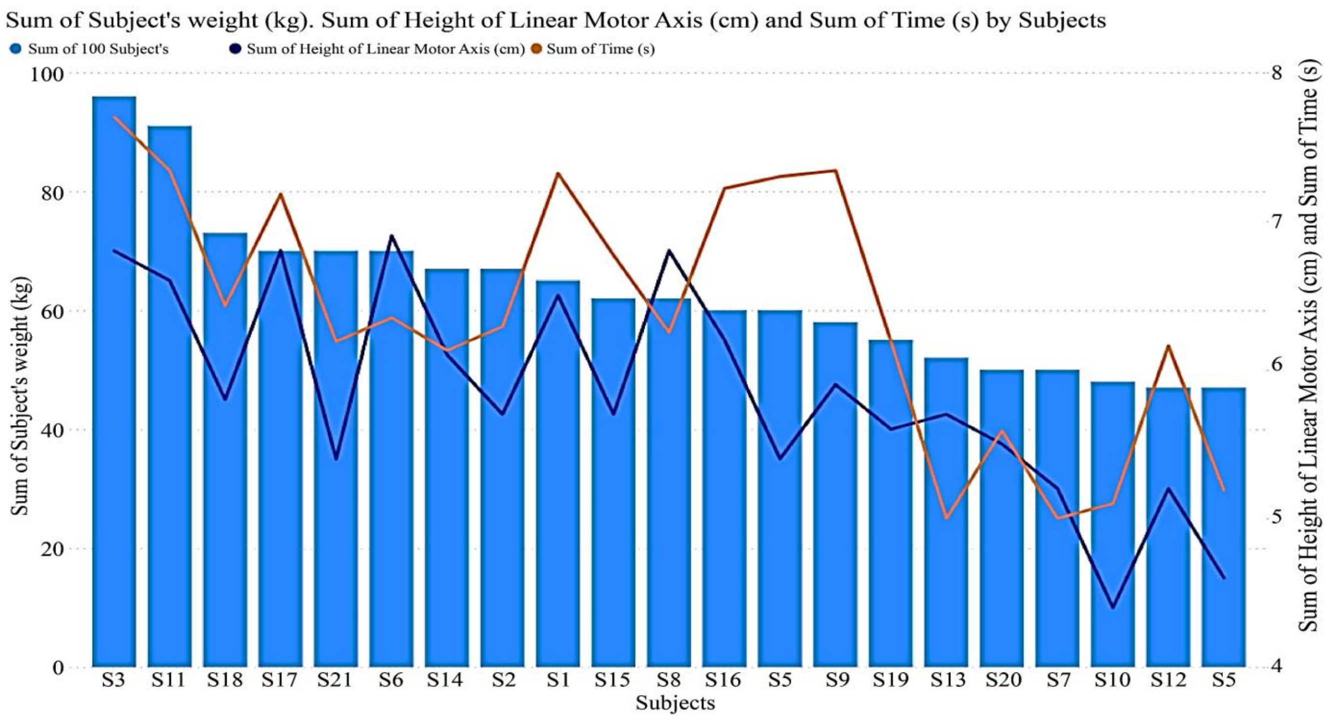


Fig. 10 Data visualization of weight, Time, and Height by subjects

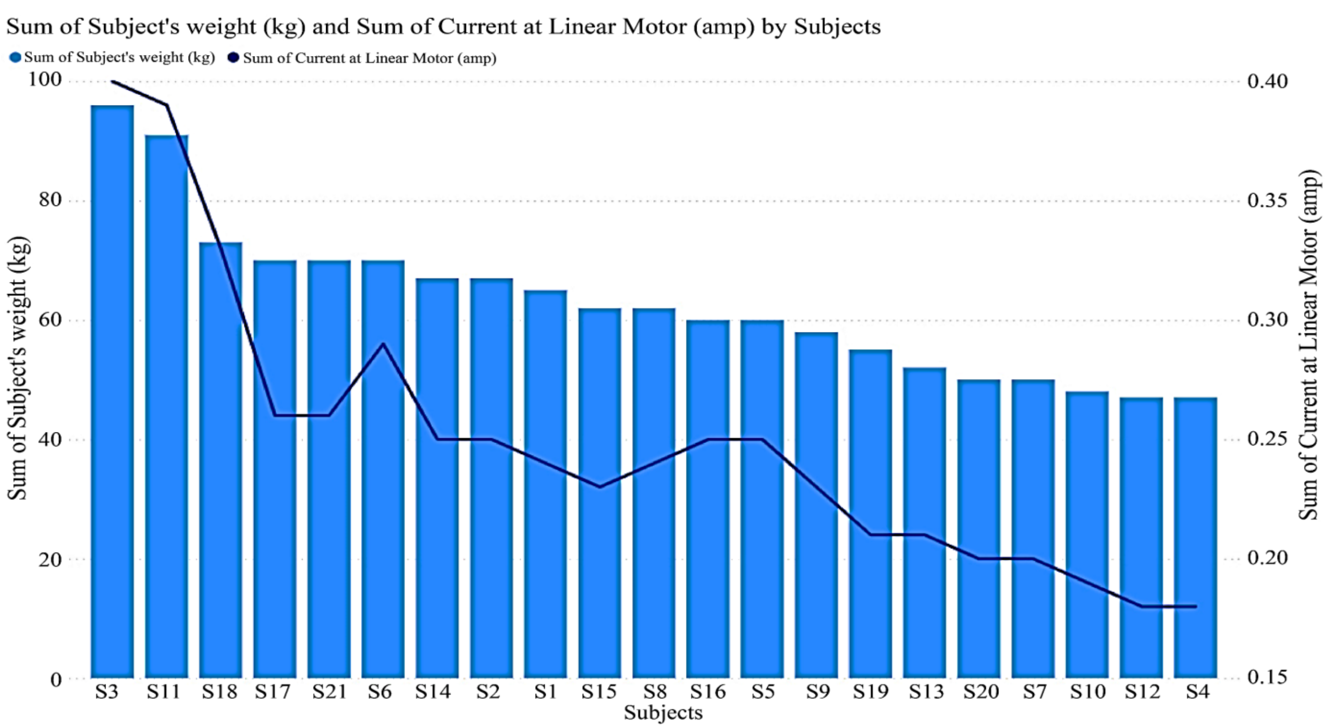


Fig. 11 Data visualization (Current and weight by subjects)

4. Conclusion

In this paper, a prototype Autonomous Height Adjustment System has been successfully created for a low-cost IoT-based office chair (around 5000 THB). Mechanical, electronic, and software designs were proposed and tested on 21 subjects. Subject data is recorded using IoT with the HTTP protocol, and MySQL is used as a database without a particular API. Future work is concerned with adding multiple sensors as measurement parameters, collecting datasets, and implementing deep/machine learning as the main algorithm of the system.

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