Mechatronic Systems and Control, Vol. 51, No. 10, 2023
An Open Access Paper

NOVEL CHAIR DESIGN TO MANAGE PRESSURE DISTRIBUTION

Hao Wu* and Grantham Pang**

Abstract

Sitting pressure distribution is closely related to sitting comfort, health, and chair ergonomics. This study describes the development of a novel chair that can monitor and adjust seat pressure with the aim of relieving seat pressure. A mat device was developed to collect pressure distribution data from the seat surface. Electric extension/retraction mechanisms were designed from the base of the seat to redistribute seat pressure. Evaluations are presented for monitoring the pressure distributions of three different seat materials when a person was in four different postures, demonstrating that the performance of the pressure sensing mats was satisfactory. In an evaluation of the efficacy of the electric extenders' mechatronics features, the retraction function is viable for decreasing surface pressure. We expect that this study will contribute to novel chair design, and successful engineering development could contribute to the prevention of pressure ulcers by adjusting seat pressure for people in prolonged sitting positions.

Key Words

Seat design, comfort, pressure distribution

1. Introduction

Prolonged sitting is highly common and can cause discomfort and health-related problems. Many factors affect seat comfort, including pressure distribution, vibration, temperature, and backrest inclination. In this study, we focus on one aspect of sitting: pressure distribution. Seat comfort has been studied for office seats [1]–[3], aircraft seats [4], [5], automobile seats [6]–[8], and classroom seats [9], [10]. A relationship is believed to exist between subjective comfort/discomfort and objective measurements of body pressure distribution. The comfort level of a chair is of critical importance. [11], [12] discussed the importance of having a comfortable chair and examined how it relates to pressure distribution.

A sensor mat is used [2] to measure seating pressure distribution for office chairs, while [13] obtained body pressure distribution data from a pressure mat placed on different seat cushions. Unsupervised deep learning methods have been used to analyse the collected sensory information. [14] aimed to develop smart chairs for monitoring the sitting behaviour of office workers. In work by [15], pressure sensitivity was measured at different points in contact with the seat pan and backrest of a vehicle seat. The values of the forces at which the pressure started to create discomfort were also recorded. Many other studies have reported that seat comfort is related to pressure distribution. The study by [16] aimed to help seat designers evaluate the designs and occupant positioning. The work of [17] focussed on obtaining a desirable pressure distribution in an aircraft passenger seat due to the discomfort caused by long-term sitting. The new design would allow an adjustment to the seat's surface curvature to decentralise the pressure distribution.

Some studies have described the relationship between discomfort and pressure distribution. A measurement device [18] was developed for recording comfort relevant seat parameters. The factors affecting automobile seat cushion comfort in static conditions were examined in [19]. The design of automobile seats is investigated in [20] with an ideal pressure distribution. Obtaining the largest contact surface between the human and the user seems to be the objective. This work achieved real-time measurement of pressure distribution and related it to the comfort model of the user [21] and described the design of a passenger seat for commuter trains. Different postures and seats have been evaluated. Pressure distribution data on the cushions were then collected for seat improvement. Research by [22] focussed on comfort design in passenger train seats. Different seat contour designs would lead to different pressure mapping data on the seat surface for every posture. This study recognised that there is no agreement from academic works on what is considered an ideal pressure distribution.

For office workers, prolonged sitting is very common and increases the risk of lower back pain. [23] aimed to investigate seat pressure distribution characteristics

* College of Electronics and Information Engineering, Shenzhen University, Shenzhen, Guangdong 518060, China; e-mail: wuhao@szu.edu.cn
** Department of Electrical and Electronic Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong; e-mail: gpang@eee.hku.hk
Corresponding author: Hao Wu

(DOI: 10.2316/J.2023.201-0390)

based on data collected from pressure mat device and associated it to workers with and without chronic lower back pain. An active sitting chair, called CoreChair, was developed by [24]. CoreChair contains a multi-axis seat pan allowing slight movement while seated. Hence, it would help mitigate the problem of long-term static sitting that leads to reduced blood flow to the lower limbs. From the evaluation, it was noted that subjects sitting on a traditional chair exhibited increased attention-task errors compared to subjects sitting on the CoreChair. A chair was developed in [25] and [26] with pressure sensing capability in an effort to classify the sitting posture of the person sitting on it. Current seat pressure measurement devices on the market include the Xsensor X3 medical seat and back system [27], [28]. However, the chairs must connect to a computer to display and evaluate pressure.

In recent years, many engineering technologies have been applied on biomedical and health care. The design of a mechatronic orthosis used as home-based rehabilitation for elbow-injured patients is given in [29]. In the area of chair design, [30] proposed a blood pressure monitoring system by equipping an electrocardiograph (ECG), a photoplethysmography (PPG), and a control model to a chair, which could measure ECG and PPG signals so as to calculate the continuous pulse time. It must be noted that the pressure distribution of a chair is also highly related to healthcare with respect to decreasing the risk of pressure ulcer development. Pressure ulcers are caused by pressure, or pressure together with shear and friction forces to the skin [31]–[33]. Individuals who often experience prolonged periods of sitting or lying down are at high risk for pressure ulcer development, including frail and weak older people and those with spinal cord injuries. Hence, it is desirable to redistribute the pressure to the skin on a chair. However, those who are weak or sick may not be able to adjust their positions on their own to reduce seat pressure on a specific region of a chair. Therefore, a chair that has mechatronics to measure and redistribute seat pressure is desirable.

2. Methods

Figure 1 shows a novel chair that was developed with five parts: a chair framework with aluminium products, a seat cushion, ten electric extenders at the base of the chair, a pressure sensor mat with 16 sensors, and an electronic board for display and extender control. In this study, the surface pressure of the chair was recorded for ten participants, and the extenders were controlled to adjust the seat pressure by extending or retracting the extender lengths. Seat surface pressure can be reduced on either the left-hand side (LHS) or right-hand side (RHS) of the chair. During the evaluation, each participant would sit on the chair and then lean the body to different directions, while the seat pressure is recorded in real time by the pressure sensor mat. The seat pressure distribution is affected by the surface material. Three seat materials (plastic board, cotton-padded cushion, and specialised pressure-relieving cushion) have been used for evaluation.

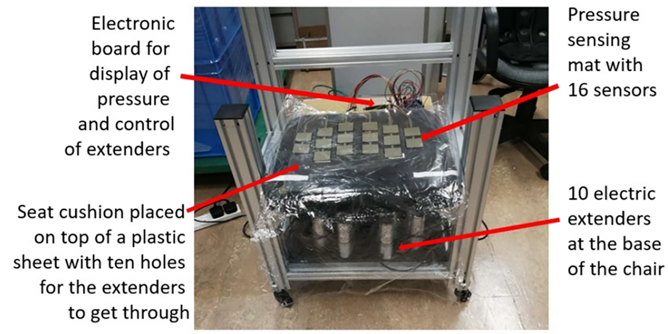

Figure 1. Experimental setup of the developed chair.

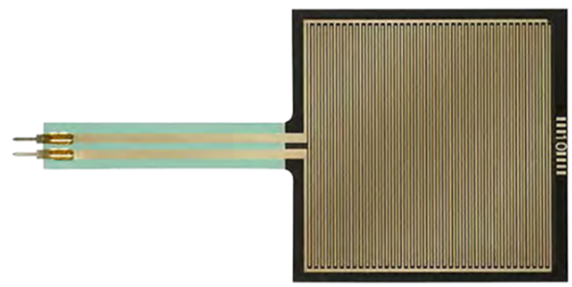

Figure 2. A photo of the thin-sheet force sensor.

2.1 Equipment

2.1.1 Construction of the Seat Pressure Sensor Mat

One primary task was the construction of a state-of-the-art pressure-sensing mat, involving an array of 16 pressure sensors. Figure 2 shows an image of the thin-sheet force sensor [34]. The 16 sensors are placed on a flexible thin sheet (figure 3) on a seat cushion before a participant sits on top. The sensors are made of robust polymer thick film. Each of the sensors senses a range of force from approximately 0.2 N to 20 N. When a person sits on them, a sensor translates the exerted force to a decrease in resistance. Figure 3 shows the final implementation of the 16 sensors placed on a thin plastic sheet. The pressure-sensing mat on the seat covers an area of 35 cm by 25 cm, similar to the contact area of the buttocks when a person sits.

2.1.2 Display of the Sensor Readings

The pressure-sensing mat connects to an Arduino microcontroller board, which serves as the processor [35]. A display device, Adafruit 2.8″ TFT LCD, is used to display the pressure distribution obtained in real time as shown in Fig. 4. The advanced sensors, together with the electronics, provide real-time measurement and display of the pressure levels at the 16 locations on the chair which would reflect the pressure being applied on the skin of the participant. The level of pressure experienced by the sensor is represented by the displayed value. Sensor readings have been scaled to a range between 0 and 1,100. In the final

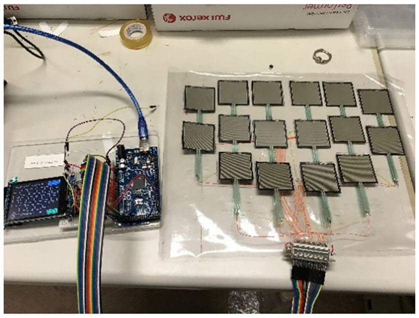

Figure 3. Setup of the 16 pressure sensors.

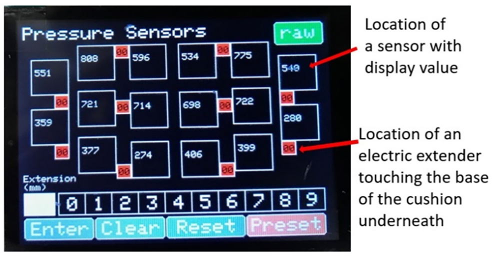

Figure 4. Screen display showing the 16 sensor readings.

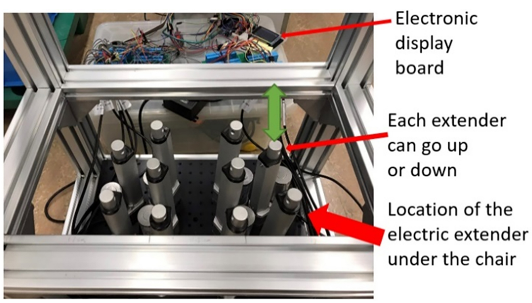

Figure 5. Electric extenders are put under the chair.

presentation, values are rescaled to a range between 0 and 100. The red touch screen buttons are for controlling the extension of the ten electric extenders. For more detailed analysis, the pressure readings may also be divided into different zones. Figure 10 shows the left and right zones, and Fig. 11 shows the sitting region into the front and back zones.

2.1.3 Electric Extender Construction

The main objective of this study was to adjust a seat's surface pressure distribution in real time. Figure 5 shows the implemented ten electric extenders located at the base of the chair. Figure 6 shows the plastic sheet on which the seat cushion can be placed, and the participant then sits on top. Note the ten holes on the plastic sheet that are designed for the ten extenders to pass through and touch the base of the seat cushion. This mechanism is designed to adjust the seat surface pressure. The extension and retraction control functions of the extenders are performed through the output pins of the Arduino microcontroller board.

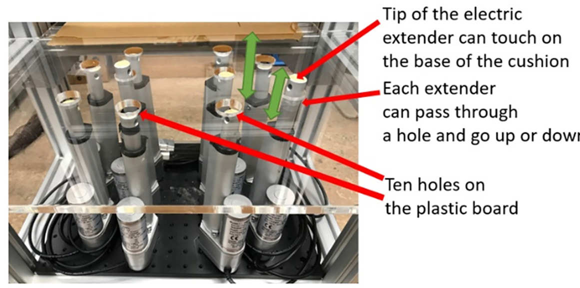

Figure 6. A plastic surface with ten holes for the electric extenders to pass through.

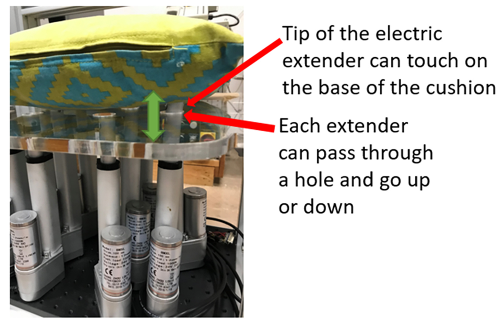

Figure 7. A cushion placed on the plastic sheet.

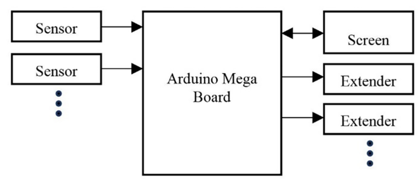

Figure 8. Block diagram of the hardware system.

Figure 7 shows a cushion placed on the plastic sheet with holes for the electric extenders to touch at the bottom of the cushion, hence adjusting the pressure distribution at the top where a person sits. Figure 8 depicts the block diagram showing the sensors, Arduino board, display screen, and extenders. The inputs to the Arduino board are the 16 sensor readings, which are collected through the analogue pins of the board. The board is connected to a touch screen, as well as ten electric extenders. The variation of pressure distribution is visualised and displayed in real time as graphics on the screen. The touch screen also acts as a control panel. Users can control the extension of the extenders through the touch screen by pressing the buttons. When in a sitting position, the pressure is usually high on the buttocks, especially where the bones are located. The sitting area may be divided into six regions (Fig. 9). The red circles, labelled A–J, represent the positions of the extenders, and the squares show the location of the pressure sensors.

2.2 Participants and Procedure

The study involved ten participants, ranging in age from 20 to 25. Data were gathered on weight and height.

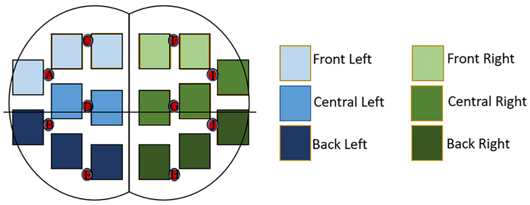

Figure 9. Seat is divided into six sitting regions.

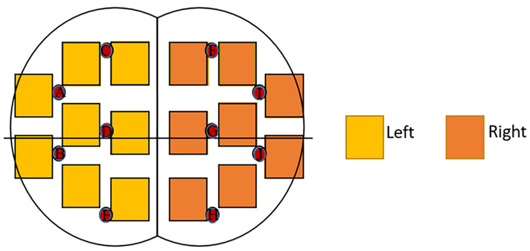

Figure 10. Seat is divided into left and right zones.

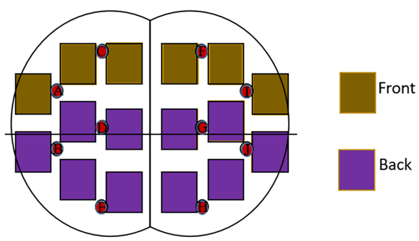

Figure 11. Seat is divided into front and back zones.

Figure 12. The plastic board with the sensor mat.

Subjects were asked to sit on the chair, which was covered with different seat cushions, and the pressure-sensing mat was placed on top of the seat material before a subject sat on the chair. The subjects were then asked to sit in different postures: normal position (sitting with the back vertical); sitting with the body leaning slightly to the right; sitting with the body leaning slightly to the left; and sitting with the body leaning slightly forward. Finally, each participant was asked to return to a normal sitting position. Then, one extender was retracted from the base on the LHS, then followed by the retraction of a second extender to monitor the pressure reduction on the LHS. The same procedure was repeated on the RHS for pressure reduction.

3. System Evaluation

3.1 Test of Various Postures and Seat Materials

We tested how sitting posture and seat material influenced sitting pressure distribution to verify the function of the sensing mats. Four sitting postures and three seat materials were tested. The different postures were as follows:

- normal position (sitting with the back vertical);
- sitting with the body leaning slightly to the right;
- sitting with the body leaning slightly to the left;
- sitting with the body leaning slightly forward.

The three seat materials were as follows:

- plastic board;
- cotton-padded cushion;
- specialised pressure-relieving cushion approximately 2.5 cm thick and made of foam material designed to even out the surface pressure.

Participants weighed approximately 57 kg. For sitting on each seat material, each person completed the four sitting postures. For the ease of showing pressure distribution results, the raw data on pressure collected from the 16 sensors on the chair were displayed using MATLAB.

3.2 Plastic Board

Figure 12 shows the plastic board with the sensing mat. The pressure distribution of four different postures is shown in Figs. 13(a)–(d).

3.3 Cotton-padded Cushion

Figure 14 shows the cotton-padded cushion and the sensor mat on the chair. Pressure distributions of the buttocks in different postures on the cotton-padded cushion are shown in Fig. 15(a)–(d).

3.4 Specialised Pressure-relieving Cushion

Figure 16 shows a specialised pressure-relieving cushion designed to avoid the build-up of any high-pressure spot on the surface. The sensor mat was placed on the top. Pressure distributions of the buttocks at different postures are shown in Fig. 17. Pressure on the specialised pressure-relieving cushion surface was indeed less when compared with other seat materials. No high pressure regions of orange or red colours can be observed from all figures of Fig. 17.

The images of Figs. 13, 15, and 17 give the different patterns of seating pressure variation associated with different class of leaning directions. Repeated evaluations of the chair with different seat materials would further contribute to more classes of pattern. Classification of these patterns can be carried out with the use of a fuzzy similarity function as discussed in [36].

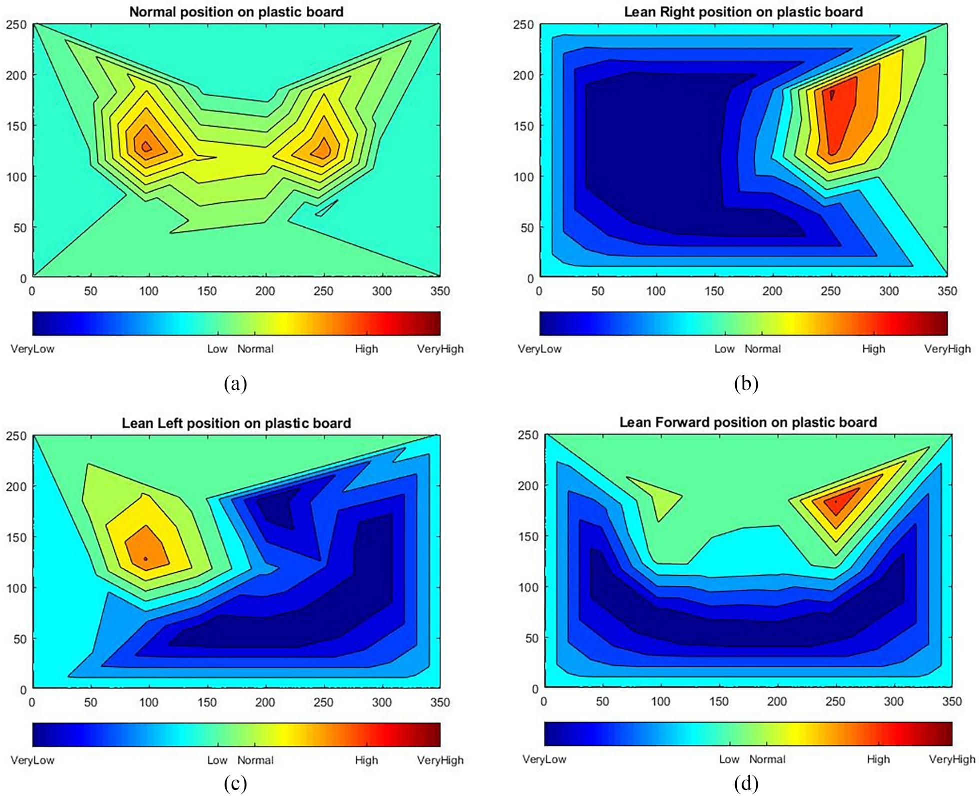

Figure 13. (a) Normal sitting position on plastic board; (b) lean-right sitting position on plastic board; (c) lean-left sitting position on plastic board; and (d) lean-forward sitting position on plastic board.

Figure 14. A cotton-padded cushion with a sensing mat.

4. System Evaluation

4.1 Pressure Reduction by Retraction of the Electric Extenders

In this section, the performance of the developed pressure sensing mat and electric extender system was evaluated. We examined whether the pressure level of a particular sitting region could be adjusted using the extenders. Each participant remained in an upright sitting position throughout the experiment without leaning in any direction. Since the ultimate goal is to provide a comfortable and even pressure distribution, the specialised pressure-relieving cushion was chosen for evaluation. The ten electric extenders at the base were all at their nominal extension positions. The tips of all ten extenders were touching at the bottom of the pressure-relieving cushion. Results revealed that with the extenders in position, retraction of one and two extenders caused a reduction of pressure in the desired region of the surface.

4.1.1 Reduction of Pressure Distribution on the Right-hand Side of the Sitting Region

One evaluation result is shown in this section. The first/top panel in Fig. 18 shows the seat pressure distribution with a participant sitting in a normal position. The second picture shows the result after the retraction of one extender from Location F, demonstrating a clear drop in pressure on the RHS. The last/bottom panel shows the result with the retraction of two extenders from both Location F and G. Further pressure reduction is observed on the RHS.

4.1.2 Analysis of Pressure Distribution Data on the Right-hand Side

The seat was divided into more detailed regions, as shown in Fig. 9. Table 1 gives the average pressure reading measured for each region. Values are all scaled to a range from 0 to 100. The first row is from the reference, normal position. The second row is the measurement taken when the electric extender at location F was engaged. The third row is when both extenders at locations F and G are

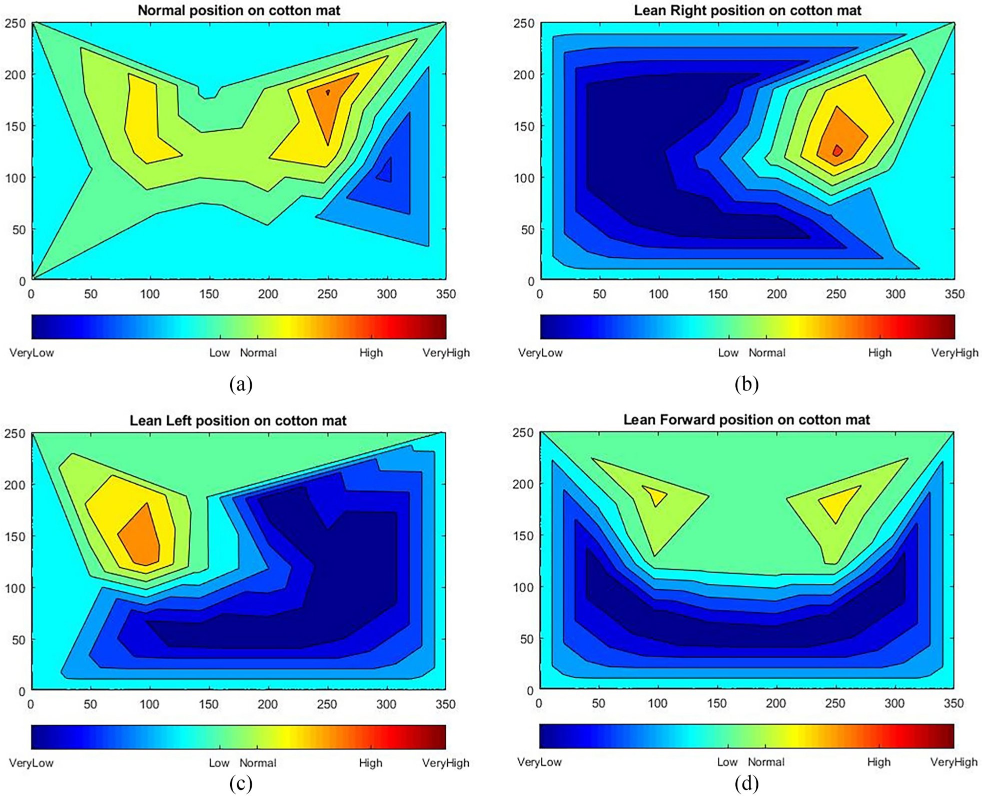

Figure 15. (a) Normal sitting position on cotton-padded cushion; (b) lean-right sitting position on cotton-padded cushion; (c) lean-left sitting position on cotton-padded cushion; and (d) lean-forward sitting position on cotton-padded cushion.

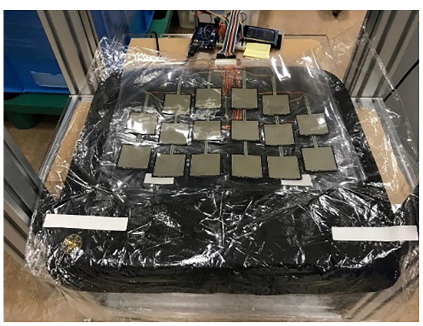

Figure 16. A specialised pressure-relieving cushion.

retracted. Of note, the values corresponding to the RHS decreased. A slight increase in values is observed on the LHS. Table 1 also shows the percent change in pressure readings from the first row (reference position) to the third row. The negative values (in bold) correspond to pressure decreases on the RHS. Another analysis of the measured data was performed by dividing the seat into additional zones (figures 10 and 11): Left, Right, Front, Back, and Overall. As shown in Table 2, the pressure was reduced on the RHS, and the percent change to the pressure readings is also presented.

4.1.3 Reduction of Pressure Distribution on the Left-hand Side of the Sitting Region

Again, a detailed evaluation was given. The top panel of Fig. 19 shows the seat pressure distribution with a participant sitting in a normal position. The picture below shows the result after the retraction of one extender from location C, clearly demonstrating that the pressure is reduced on the LHS. The bottom picture shows the result with the retraction of two extenders from Locations C and D. Further pressure reduction is observed on the LHS but a slight increase is observed on the RHS. From the data collected, the pressure was reduced on the RHS, and the percent change to the pressure readings is comparable to the RHS. A pressure reduction of 11.06% and 9.5% was reached in the Front Right and Central Right regions, respectively. The average reduction to the RHS was 7.77%.

5. Discussions

In an evaluation on the different sitting positions/postures and different seat materials in Section 3, it can be seen that the lowest pressure level was displayed in the specialised pressure-relieving cushion among three types of seat materials. Moreover, pressure at the seated bone regions (ischial tuberosity) of the buttocks was higher in all four postures. The higher-pressure location was changed to the buttock regions towards which the person leant. This situation was applied to all three seat materials, although the pressure *distribution was most even in the specialised pressure-relieving cushion.* This confirms the value on the use of pressure-relieving cushion on chairs, and such practise should be recommended.

In this study, we also aim at seat pressure reduction at targeted locations. From the results of Section 4, the

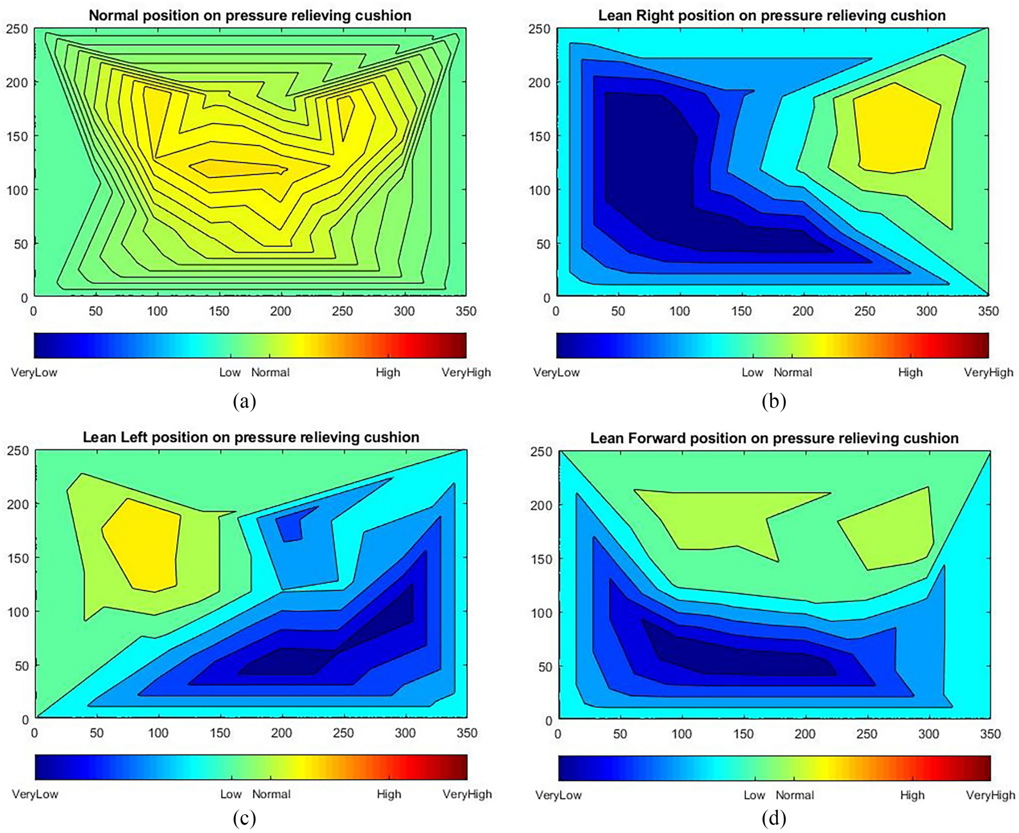

Figure 17. (a) Normal sitting position on specialised cushion; (b) lean-right sitting position on specialised cushion; (c) lean-left sitting position on specialised cushion; and (d) lean-forward sitting position on specialised cushion.

Table 1
Pressure Reading and Percentage Changes for Different Seat Regions for the Three Situations (RHS)

	Front Left	Centr. Left	Back Left	Front Right	Centr. Right	Back Right
Normal position Retract one extender Retract two extenders	59.94 61.76 62.27	65.86 67.09 67.68	58.71 59.75 59.58	60.18 57.39 53.18	65.05 58.45 58.23	60.20 57.44 56.60
Percentage Change (%)	3.89	2.76	1.49	−11.63	−10.48	−5.98

Table 2
Pressure reading and percentage changes for different zones (RHS)

	Left	Right	Front	Back	Overall
Normal position Retract one extender Retract two extenders	59.17 60.50 60.59	60.19 57.42 55.32	60.06 59.58 57.72	59.45 58.59 58.09	59.68 58.96 57.95
Percentage change (%)	2.40	−8.10	−3.89	−2.29	−2.89

developed chair system has enabled a reduction of pressure distribution on either the LHS or RHS. For some regions, such as the Front Right, Central Right, and Front Left, the drop reached approximately 10%. This is a very encouraging result for this initial study on active seat pressure reduction by the use of the mechanical device at the base of the seat. Active pressure reduction on specific regions of the seat surface can help relieve the discomfort of elders suffering from pressure ulcers.

Based on the current system evaluation, an overall reduction to the pressure on the RHS of 7.77% conveyed a slight increase to the LHS of 2.65%. There was an overall reduction of 2.6%. This is beneficial if there is a need for such a pressure shift. The reverse situation is an overall

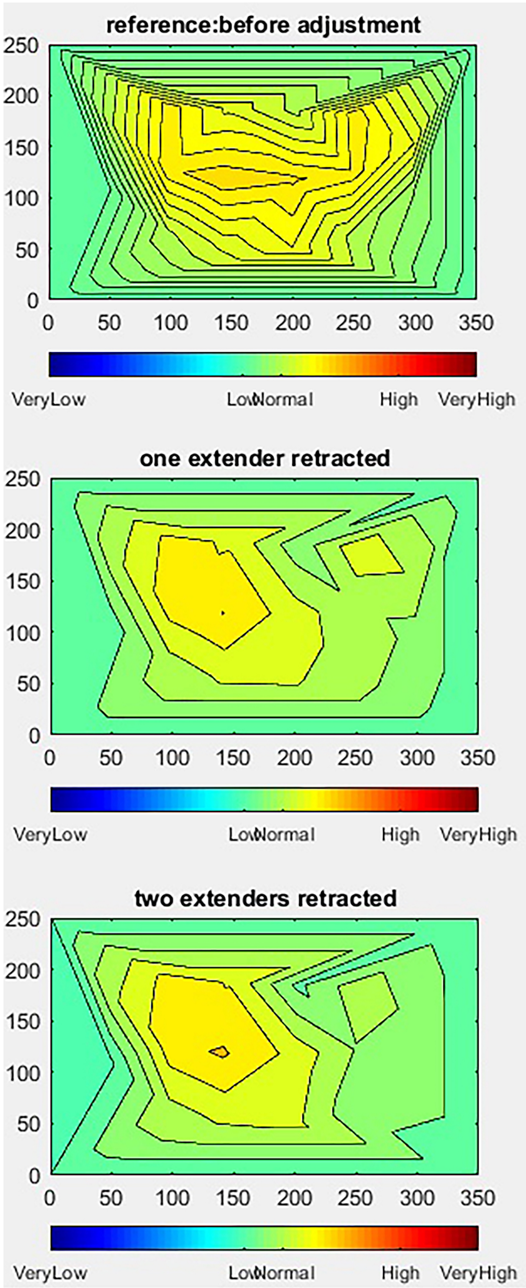

Figure 18. Pressure reduction on the RHS.

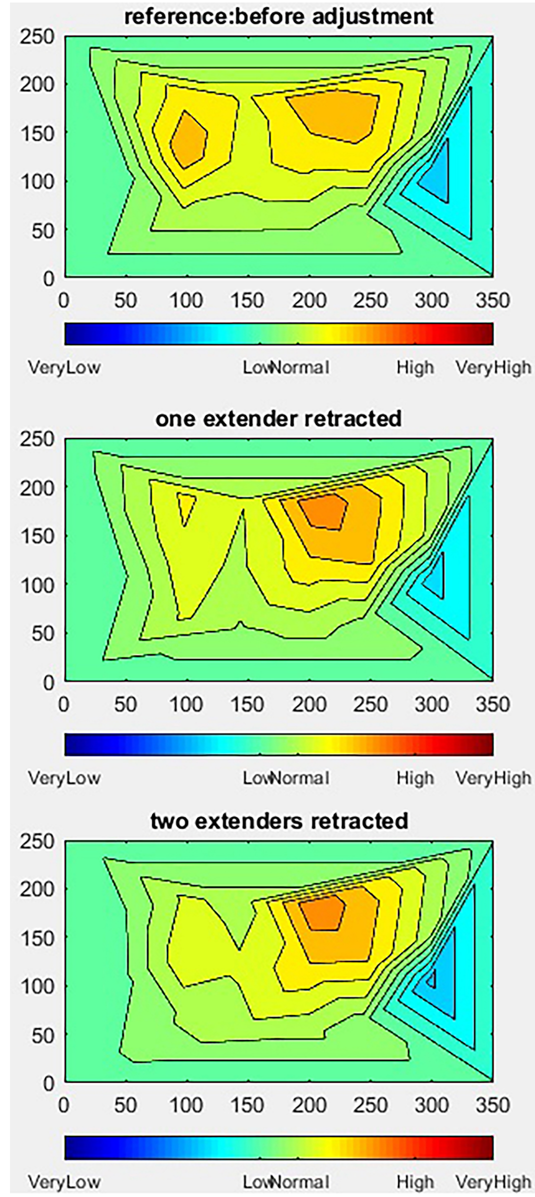

Figure 19. Pressure reduction on the LHS.

reduction to the pressure on the LHS of 6.37% with a slight increase to the RHS of 1.95%. The above result is achieved by the use of only ten extenders (with extension/retraction mechanisms). With the use of more extenders or similar device, it is believed that more precise adjustments to the pressure redistribution to the different regions and different zones can be performed in future work.

In future work, the mechatronic design of actuators at the base of the seat for controllable pressure distribution is the core research objective. The design for optimal locations of multiple extenders/retractors to achieve seat pressure distribution control is complex [37]. Presented an integrated approach of using the linear graph and genetic programming for engineering design of mechatronic systems. Reinforcement learning [38] is also a potential approach in the face of a complex situation and environment. There is very high interaction to the seat surface pressure due to the effects of the mechanical actuators at the base. [39] discussed the use of genetic algorithm for cooperative task planning.

The chair developed in this study may contribute to healthcare by preventing pressure ulcers. This chair has strong potential for use in seated people who have unavoidable and prolonged sitting positions, *e.g.*, weak and frail older people in nursing homes. Redistribution of pressure to skin on the chair with pressure-relieving seat cushions and/or bed mattresses together with the repositioning of such people is an effective method to decrease the risk of developing a pressure injury [32]. However, most weak, frail, or sick people in prolonged seated positions are unable to change positions on their own. The developed chair uses an active mechanism to alleviate the pressure on specific regions of the seat, which would be beneficial to these people.

6. Conclusion

A novel chair design that adjusts the seat's surface pressure distribution in real time was developed in this study. An extensive evaluation was performed to verify the reduction in seat surface pressure to specific regions or zones on either the LHS or RHS. A reduction to one side conveyed a slight increase to the opposite side, but the experimental results indicated that there was an overall reduction in pressure distribution. The chair allows users to reduce discomfort in a targeted seat region. The successful development of this system may also contribute to the prevention of pressure ulcers by adjusting seat pressure for people in prolonged sitting positions.

The entire system is easy to learn and user-friendly for caregivers. It has great potential to be used in healthcare settings, for example, in nursing homes where prolonged sitting is commonly unavoidable, especially for weak and frail older people. The risk of pressure ulcer development would be decreased, and early-stage pressure ulcers could be treated through the pressure adjustment functions on a specified region of the chair to decrease the buttocks pressure of seated older people. Users can also be trained to use this system for self-controlling sitting pressure.

The active adjustment of seat surface pressure for a chair is highly desirable for both comfort and healthcare concerns. This paper has shown that such a mechatronics chair can be achieved. Further work should be performed to further reduce the pressure by fine-tuning of the retraction/extension of the electric extenders or by using additional extenders. A careful study on the number of such devices and their distribution should be carried out. The coordination of them for an optimal/desirable pressure distribution is also crucial. Deep learning methods can also be implemented to fine-tune the electric extenders to attain the desired adjustment to the target region or zone.

References

[1] E. Weston, P. Le, and W.S. Marras, A biomechanical and physiological study of office seat and tablet device interaction, *Applied Ergonomics, 62*, 2017, 83–93, doi: 10.1016/j.apergo.2017.02.013.

[2] R. Zemp, W.R. Taylor, and S. Lorenzetti, Seat pan and backrest pressure distribution while sitting in office chairs, *Applied Ergonomics, 53*, 2016, 1–9, doi: 10.1016/j.apergo.2015.08.004.

[3] C. Rosaria, N. Alessandro, and C. Chiara, Comfort seat design: Thermal sensitivity of human back and buttock, *International Journal of Industrial Ergonomics, 78*, 2020, 102961, doi: 10.1016/j.ergon.2020.102961.

[4] A. Vanacore, A. Lanzotti, C. Percuoco, A. Capasso, and B. Vitolo, Design and analysis of comparative experiments to assess the (dis-)comfort of aircraft seating, *Applied Ergonomics, 76*, 2019, 155–163, doi: 10.1016/j.apergo.2018.12.012.

[5] C. Zhao, S. Yu, C. Harris Adamson, S. Ali, W. Li, and Q. Li, Effects of aircraft seat pitch on interface pressure and passenger discomfort, *International Journal of Industrial Ergonomics, 76*, 2020, 102900, doi: 10.1016/j.ergon.2019.102900.

[6] N. Mansfield, G. Sammonds, and L. Nguyen, Driver discomfort in vehicle seats – Effect of changing road conditions and seat foam composition, *Applied Ergonomics, 50*, 2015, 153–159.

[7] M. Romelfanger and M. Kolich, Comfortable automotive seat design and big data analytics: A study in thigh support, *Applied Ergonomics, 75*, 2019, 257–262, doi: 10.1016/j.apergo.2018.08.020.

[8] D.Y. Kim, J.H. Bang, C.A. Lee, H.Y. Kim, K.Y. Choi, and B.G. Lim, Numerical evaluation of time-dependent sagging for low density polyurethane foams to apply the long-term driving comfort on the seat cushion design, *International Journal of Industrial Ergonomics, 64*, 2018, 178–187, doi: 10.1016/j.ergon.2016.08.010.

[9] L. Fasulo, A. Naddeo, and N. Cappetti, A study of classroom seat (dis)comfort: Relationships between body movements, center of pressure on the seat, and lower limbs' sensations, *Applied Ergonomics, 74*, 2019, 233–240, doi: 10.1016/j.apergo.2018.08.021.

[10] E. Kahya, Mismatch between classroom furniture and anthropometric measures of university students, *International Journal of Industrial Ergonomics, 74*, 2019, 102864.

[11] Y.-D. Jun, E. Cho, and S.-H. Park, Comfort evaluation of a coccyx seating mat based on body pressure measurements, *Information (Japan), 20*, 2017, 3657–3666.

[12] M. Makhsous, F. Lin, D. Hanawalt, S.L. Kruger, and A. LaMantia, The effect of chair designs on sitting pressure distribution and tissue perfusion, *Hum Factors, 54*(6), 2012, 1066–1074, doi: 10.1177/0018720812457681.

[13] R. Mitsuya, K. Kato, N. Kou, T. Nakamura, K. Sugawara, D. Hiroki, S. Takuro, and K. Takashi, Analysis of body pressure distribution on car seats by using deep learning, *Applied Ergonomics, 75*, 2019, 283–287, doi: 10.1016/j.apergo.2018.08.023.

[14] C. C. Roossien, J. Stegenga, A.P. Hodselmans, S.M. Spook, W. Koolhaas, S. Brouwer, G.J. Verkerke, and M.F. Reneman, Can a smart chair improve the sitting behavior of office workers? *Applied Ergonomics, 65*, 2017, 355–361, doi: 10.1016/j.apergo.2017.07.012.

[15] P. Vink and D. Lips, Sensitivity of the human back and buttocks: The missing link in comfort seat design, *Applied Ergonomics, 58*, 2017, 287–292, doi: 10.1016/j.apergo.2016.07.004.

[16] J.P. Drost, M.D. Shafer, and T.R. Bush, Comfortable leg splay of mid-sized males in automotive seats, *Applied Ergonomics, 85*, 2020, 103062, doi: 10.1016/j.apergo.2020.103062.

[17] G.H. Campos and F. (Jeff) Xi, Pressure sensing of an aircraft passenger seat with lumbar control, *Applied Ergonomics, 84*, 2020, 103006, doi: 10.1016/j.apergo.2019.103006.

[18] M. Wegner, R. Martic, M. Franz, and P. Vink, A system to measure seat-human interaction parameters which might be comfort relevant, *Applied Ergonomics, 84*, 2020, 103008, doi: 10.1016/j.apergo.2019.103008.

[19] K. Ebe and M.J. Griffin, Factors affecting static seat cushion comfort, *Ergonomics, 44*(10), 2001, 901–921, doi: 10.1080/00140130110064685.

[20] U. Kilincsoy, A. Wagner, P. Vink, and H. Bubb, Application of ideal pressure distribution in development process of automobile seats, *Work, 54*(4), 2016, 895–904, doi: 10.3233/WOR-162350.

[21] R.E. Bronkhorst and F. Krause, Designing comfortable passenger seats. (Boca Raton: CRC Press, 2005).

[22] R. Mastenbroek and A. Kiese, EUROSPEC Seat Comfort - spread academic news in the railway world, Proc. 2nd International Comfort Congress, Delft, 2019.

[23] N. Akkarakittichoke and P. Janwantanakul, Seat pressure distribution characteristics during 1 hour sitting in office workers with and without chronic low back pain, *Safety and Health at Work, 8*(2), 2017, 212–219, doi: 10.1016/j.shaw.2016.10.005.

[24] J. Triglav, E. Howe, J. Cheema, B. Dube, M.J. Fenske, S. Nicholas, and B. Leah, Physiological and cognitive measures during prolonged sitting: Comparisons between a standard and multi-axial office chair, *Applied Ergonomics, 78*, 176–183, 2019, doi: 10.1016/j.apergo.2019.03.002.

[25] H.Z. Tan, L.A. Slivovsky, and A. Pentland, A sensing chair using pressure distribution sensors, *IEEE/ASME Transactions on Mechatronics, 6*(3), 2001, 261–268, doi: 10.1109/3516.951364.

[26] I. Daian, A.M. van Ruiten, A. Visser, and S. Zubic, Sensitive chair: A force sensing chair with multimodal real-time feedback *via* agent, *Proc. of the 14th European Conf. on Cognitive ergonomics - ECCE '07*, London, United Kingdom, 2007, 163, doi: 10.1145/1362550.1362583.

[27] XSENSOR, X3 medical seat & back system, http://www.xsensor.com/.

[28] Tekscan: Pressure mapping, force measurement & tactile sensors, http://www.tekscan.com.

[29] V.T. Minh, M. Tamre, A. Safonov, V. Musalimov, and P. Kovalenko, Design and implementation of a mechatronic elbow orthosis, *Mechatronic Systems and Control, Calgary 48*(4), 2020, doi:10.2316/J.2020.201-0056.

[30] Z. Tang, T. Tamura, M. Sekine, M. Huang, W. Chen, M. Yoshida, K. Sakatani, H. Kobayashi, and S. Kanaya, A chair–based unobtrusive cuffless blood pressure monitoring system based on pulse arrival time, *IEEE Journal of Biomedical and Health Informatics, 21*(5), 2017, 1194–1205, doi: 10.1109/JBHI.2016.2614962.

[31] E.P.U.A. Panel and N.P.U.A. Panel, Prevention and treatment of pressure ulcers: Quick reference guide, 2009. [Online]. Available: http://www.researchgate.net/publication/306032532_Prevention_and_treatment_of_pressure_ulcers_quick_reference_guide (accessed Jul. 13, 2020).

[32] J.F. Neves and K. Stancato, Pressure ulcers: A perspective of cost management in nursing services, *Journal of Nursing Ufpe,* 2012. [Online]. Available: http://connection.ebscohost.com/c/articles/78577600/pressure-ulcers-perspective\-cost-management-nursing-services (accessed Jul. 13, 2020).

[33] J. Bian and F. Modave, The rapid growth of intelligent systems in health and health care, *Health Informatics Journal*, *26*(1), 2020, 5–7.

[34] Trossen Robotics, FSR 406 Data Sheet. [Online]. Available: https://www.trossenrobotics.com/productdocs/2010-10-26-datasheet-fsr406-layout2.pdf.

[35] Arduino open-source electronic prototyping platform, https://www.arduino.cc/

[36] M. Versaci, G. Angiulli, P. Crucitti, D. De Carlo, F. Laganá, D. Pellicanò, and A. Palumbo, A fuzzy similarity-based approach to classify numerically simulated and experimentally detected carbon fiber-reinforced polymer plate defects, *Sensors 22*(11), 2022, 4232, doi: 10.3390/s22114232.

[37] E. McCormick, H. Lang, and C.W. de Silva, Automated multi-domain engineering design through linear graphs and genetic programming, *Mechatronic Systems and Control, Calgary 50*(3), 2022. doi: 10.2316/J.2022.201-0295.

[38] J. Sweafford and F. Fahimi, Model-free online reinforcement learning of a robotic manipulator, *Mechatronic Systems and Control*, *Calgary 47*(3), 2019, 136–143. doi: 10.2316/J.2019.201-2931.

[39] L. Geng, Y.F. Zhang, J.J. Wang, J.Y.H. Fuh, and S.H. Teo, Cooperative task planning for multiple unmanned aerial vehicles using genetic algorithm, *Control and Intelligent Systems*, *Calgary 42*(2), 2014. doi: 10.2316/Journal.201.2014.2.201-2562.

Biographies

Hao Wu received the B.Sc. degree from the Nanjing University of Posts and Telecommunications, and the M.Sc. and Ph.D. degrees from The University of Hong Kong. Then, he joined Tencent as a Research Fellow. He is currently an Assistant Professor with the College of Electronics and Information Engineering, Shenzhen University. His research has primarily focussed on developing novel algorithms and techniques for computational intelligence, optimisation algorithms, and machine learning, with emphasis on their applications in healthcare wearable and monitoring devices, and electric vehicle charging scheduling.

Grantham Pang received the Ph.D. degree from the University of Cambridge in 1986. He then joined the Department of Electrical and Computer Engineering, University of Waterloo, Canada, and later joined The University of Hong Kong in 1996. His research interests include artificial intelligence, convolutional neural networks, intelligent transportation systems, electronic circuit design, machine vision for surface defect detection, LED system for communications, expert systems for control system design, and intelligent control.