ActiveErgo: Automatic and Personalized Ergonomics using Self-actuating Furniture

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ABSTRACT
Proper ergonomics improves productivity and reduces risks for injuries such as tendinosis, tension neck syndrome, and back injuries. Despite having ergonomics standards and guidelines for computer usage since the 1980s, injuries due to poor ergonomics remain widespread. We present ActiveErgo, the first active approach to improving ergonomics by combining sensing and actuation of motorized furniture. It provides automatic and personalized ergonomics of computer workspaces in accordance to the recommended ergonomics guidelines. Our prototype system uses a Microsoft Kinect sensor for skeletal sensing and monitoring to determine the ideal furniture positions for each user, then uses a combination of automatic adjustment and real-time feedback to adjust the computer monitor, desk, and chair positions. Results from our 12-person user study demonstrated that ActiveErgo significantly improves ergonomics compared to manual configuration in both speed and accuracy, and helps significantly more users to fully meet ergonomics guidelines.

ACM Classification Keywords
H.5.2. User Interfaces: Ergonomics, Evaluation/methodology, Prototyping, User-centered design

Author Keywords
Ergonomics, active, adaptive, personalized, workspace, personalized

INTRODUCTION
Personal computing is becoming more essential for work, study, and entertainment, and its usage while sitting has steadily increased [21, 22, 40, 41]. Proper ergonomics improves productivity and reduces risks of musculoskeletal disorders (MSD) [21, 40, 41], especially for Repetitive Strain Injuries (RSI) such as tendinosis, tension neck syndrome, and back injuries due to prolonged computer usage [7, 36, 42].

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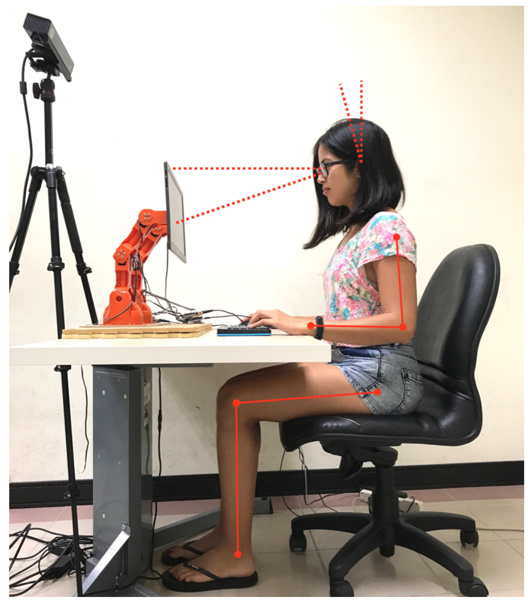

Figure 1. ActiveErgo is the first active approach to improving ergonomics by providing automatic and personalized computer workspace adjustment. Our prototype uses a Microsoft Kinect sensor for skeletal tracking and uses robotic arms and motorized desk to provide automatic workspace adjustment.

Ergonomics standards and guidelines provide specific and quantifiable recommendations for proper postures and environment settings, and has been established since the 1980s [44]. For example, desk height should be positioned such that the user's forearms are parallel to the ground. However, in order for the guidelines to be properly implemented, users need to learn the guidelines, self-monitor their postures, and manually adjust their workspaces accordingly. In practice, despite having ergonomics guidelines, conservative estimates of the annual costs caused by repetitive strain injuries (RSI) are about $50 billion in the United States alone [16].

To better understand how well ergonomic guidelines are implemented in practice,we conducted a 21-person contextual field study to measure the participants' postures while using computers in their own home, at school, and at a Fortune 500 company work environment. Results showed that every participant had ergonomics problems. Reasons included lack of ergonomics knowledge, laziness when using shared workspaces, and inaccurate estimates of their own postures.

We present ActiveErgo, the first active approach to improve ergonomics by combining sensing and self-actuating workspace furniture. Our work provides automatic, accurate, and personalized ergonomics in accordance to the ergonomics guidelines with minimal user effort. ActiveErgo uses the Microsoft Kinect's skeletal tracking to calculate the proper workspace furniture settings, and automatically actuates the desk and monitor arms to be positioned accordingly. For a non-motorized chair, our system relies on the Kinect to sense the sitting distance and the ultrasonic distance sensors to monitor the chair height, and subsequently provides real-time feedback for users to make proper adjustments.

We conducted a 12-person study to compare our system to manual adjustments based on ergonomics guidelines. Results showed that our system significantly reduced deviation from the recommended posture angles by 51.4% compared to the manual approach. In terms of configuration speed, our system spent an average of 43 seconds and was 2.2 times faster than the manual approach, which is especially important for shared workspaces that need to be re-configured for each user. Overall, our system assisted 83% of the participants in satisfying ergonomics guidelines compared to 8% with the manual approach to within a margin of 10°).

RELATED WORK

There has been significant work in each of the areas of posture sensing, ergonomics reminders, and active furniture. Our work is the first to combine all three to provide automatic and personalized ergonomics.

Posture Sensing

Accelerometers in wearable devices have been used to track partial body postures [11, 15, 20] such as in smart glasses to monitor users' head tilt during computer use [39]. Flex sensors have been attached onto users' necks to detect head tilt [9] and embedded inside sleeves to detect arm angles [31]. In addition to wearable sensors, chairs have been instrumented with sensors, such as capacity sensors [8] and piezoelectric sensor [30], to detect bad postures based on pressure distribution [10, 26, 46].

Many vision-based monitoring systems have been developed to detect sitting postures [6, 17, 33]. Geometric features extracted from the user's silhouette have been used to determine the incline angle of the user's head and to track their activities [18, 19]. Face detection have been used to calculate the distance between the face and display screen to detect viewing distance and forward head tilt [13, 24, 39]. The collaborative vision network connects multiple cameras in offices to detect workers' attention, posture, and mobility [25].

Sensors from the Microsoft Kinect provide skeletal tracking, which can be used to sense improper sitting postures [29]. Our prototype uses the Kinect's sensor to measure the user's body dimensions, head tilt, and distance-to-keyboard to calculate the proper monitor position, desk height, and chair position. We also use ultrasonic distance sensors to measure the chair height.

Ergonomics Reminders

There has been a variety of approaches to deliver ergonomic reminders to the user. On-screen notifications such as icons and pop-up windows have been used to alert users of improper postures [17, 24, 29, 37, 39]. Haptic feedback via wearable devices [15, 31] and smart chairs, [10, 17, 30, 46], and ambient feedback such as flowers that bend to reflect changes in users' postures [10, 23, 43] have also been used. In addition, BeuPo [14] an application involved with various game to increase user motivation at posture correction. Our current prototype system uses real-time feedback displayed on the user's display screen, as well as automated adjustment since the chair is not motorized. The system provides real-time directions to guide users on how to adjust chair position and height.

Active Furniture

Nissan's Intelligent Parking Chair [1] autonomously senses the environment and parks itself at the proper location. Kinectic Furniture [38] utilizes affordances such as seat angle and direction to foster spontaneous conversations among strangers in public spaces. Roombots [35] are self-reconfiguring modular robots for adaptive furniture that can change shape and function. Researchers have also studied how humans react and interact with autonomous and anthropomorphic furniture, including chairs that escape when someone is about to sit on them [27], robotic trash cans [45], robotic footstools [32], and sofa-bots [34]. Our prototype uses a motorized desk for automated height adjustment, and dual robotic arms to provide automated adjustment based on sensor data on monitor height and distance.

Salli AutoSmart [3] is a similar automated workspace furniture adjustment system, which can first automatically detect user actions of reading and typing, and then adjust their monitor and desk height to those actions. Their system differs from our proposed system due to requiring users to manually configure both the monitor height and desk height for typing mode and for reading mode. Moreover, compared to Salli AutoSmart, our system provides personalized ergonomic setup automation that is significantly faster and more accurate than manual setup.

ERGONOMICS GUIDELINES

There has been extensive research on ergonomics for computer workstation design [44]. Various standards have been developed internationally, such as Europe's International Organization for Standardization ISO-9241 and North America's BIFMA G1 - 2013 Ergonomics Guideline; and nationally, such as the Australian Standard AS-3590.2, Canadian Standard Can/CSA-Z412-M89, and American Standard ANSI/ HFES-100. In addition, there are regional guidelines such as the "Australian National Code of Practice for the Prevention of Occupational Overuse Syndrome" and Hong Kong's "A Guide to Work with Computers".

[1] https://www.youtube.com/watch?v=O1D07dTILH0

Comparisons of ergonomics standards and guidelines for computer workstations in Australia, Canada, the United States, Europe, and Hong Kong show significant variations across them [44]. We compared the recommendations from the 4 standards previously mentioned and the 1 guideline from Hong Kong, and selected the most stringent among them. For example, with the forearm and upper arm postures, we adopted the Canadian standard specifying that forearms and upper arms should be horizontal and vertical, respectively. The United States standard is more relaxed and specifies that the elbow angle should range from 70° to 135°, while the Australia and Europe standards lack such recommendation.

Moreover, the standards and guidelines specify between 14 (Hong Kong) to 33 (Canada) recommendations, ranging from seat width (all 5 standards and guidelines) to forward head tilt (Canada only), for a total of 36 recommendations [44]. For the purpose of our work focusing on personalized ergonomics, we selected all posture-related recommendations that needs personalization (i.e., requiring different workspace adjustment for different users). As shown in Figure 2, these include the following 6 posture angle recommendations:

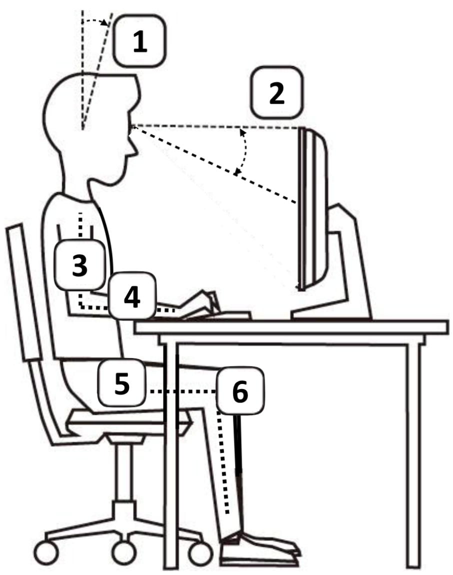

Figure 2. The 6 posture angles that require personalization in a computer workspace, based on ergonomics standards and guidelines from Europe, Canada, Australia, Hong Kong, and the United States: 1) forward head tilt, 2) vertical viewing angle, 3) upper arm to vertical, 4) lower arm to horizontal, 5) thigh to horizontal, and 6) knee angle.

- Maximum **forward head tilt** of 15°.
- **Upper arms** are vertical and **forearms** are horizontal.
- **Thighs** are horizontal and **knees** are at 90°.
- **Vertical viewing angle** of 15-20° below the horizontal, with the first line on screen at about or just below eye level.

FIELD STUDY

To better understand how ergonomics are implemented in practice, we conducted a field study in the user's context and location. We recruited 7 participants (3 females) for each of our 3 settings (home, school, and work) for a total of 21 participants. The school group is from a local university, and the work group is from a Fortune 500 internet company that provides ergonomic furniture and optional ergonomics training to all its employees. Of the 21 participants, 12 primarily used laptops and 9 primarily used desktop computers. Participants were interviewed in the context of their most-used workspaces.

We measured how ergonomic their postures were using their current workspace configuration, followed by interviews about ergonomics. In order to calculate posture angles, we used the measurement methods from Harrison *et al.* [12]. For each measurement, we used circular stickers as visual markers on each joint, including the neck, shoulder, elbow, wrist, hip (greater trochanter), knee, and ankle. We assigned a second researcher to assess the marker placement to confirm the accuracy of these stickers' placement. We then used an electric protractor [2] with a bubble level to measure the angle of the joints, and a tape ruler to measure distances. Vertical viewing angle was calculated using $\arctan(x/y)$, where x denotes the difference in height between the horizontal viewpoint and the center of the monitor, and y denotes the distance between the participant and monitor.

Results

Figure 3 shows the average deviation from the guidelines. The two largest deviations were both arm-related. The upper arm angles (mean=26.5°, SD=11.7°) were often caused by excessive chair distance to the desk/keyboard, while were forearm angles (mean=13.4°, SD = 8.7°) are caused by incorrect desk/keyboard height. Laptop users had significantly higher forward head tilt angle compared to desktop users (mean=6.58° vs. 0.88°), and the difference was statistically significant ($p < .05$).

Overall, none of the participants fully met the guidelines to within a margin of 10°. In fact, out of the total 6 posture angles, all had at least 2 angles that significantly deviated from the recommended guidelines by more than 10°. This was especially surprising for participants at their work setting (3 desktop and 4 laptop users), since the company provided ergonomic chairs, desks, and monitors, and also offered optional ergonomics training.

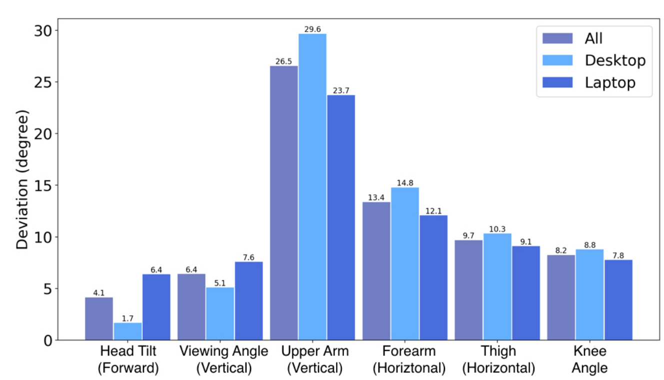

Figure 3. Results from our 21-person field research showing the average deviation from ideal postures as specified in ergonomics guidelines.

During the interview, it became clear that while most knew of ergonomics and its health/injury implications, only 33.3% of the participants could correctly specify one or more correct ergonomics guidelines. 61.9% of the participants adjusted their workspace purely based on comfort, without any specific guidelines in mind. Even after learning about proper posture angles, several participants mentioned that they would have difficulty adjusting the workspace because they did not have a good sense of their own postures angles. Finally, participants of shared workspaces mentioned that they were usually too lazy to adjust their workspaces for ergonomics, even when they expected to use them for several hours.

SYSTEM DESIGN

In order to address the barriers in adopting ergonomics guidelines and to provide personalized ergonomics, the system should be able to calculate the proper furniture height and position and to make the necessary adjustments. Ideally, all automated adjustments should be completed before the user sits down and starts using the computer to avoid unexpected furniture movement.

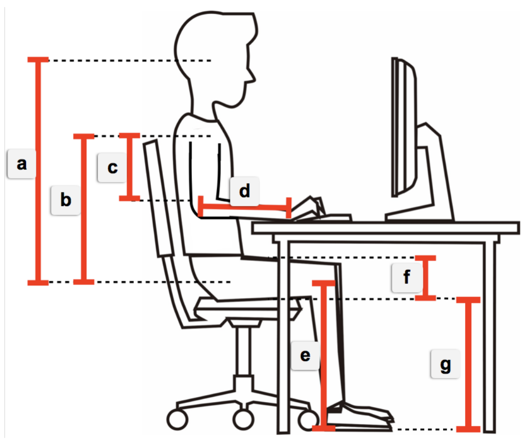

Figure 4. The 7 body dimensions measured using the Kinect sensor and used to calculate the personalized workspace settings, including: (a) hip to head, (b) torso, (c) upper arm, (d) forearm, (e) lower leg, (f) thigh thickness and (g) popliteal height.

1. **Chair height:** Affects the thigh and knee angles, and should be set to the height of the user's popliteal height shown as g in Figure 4.

$$Height_{Chair} = Height_{Popliteal} \tag{1}$$

where the popliteal height can be calculated by

$$Height_{Popliteal} = Length_{LowerLeg} - \frac{Thickness_{Thigh}}{2} \tag{2}$$

2. **Desk height:** Affects the forearm angle. After the chair height has been determined, the ideal desk height can be calculated by

$$Height_{Desk} = Height_{Chair} + Length_{ElbowToHip} \tag{3}$$

where the length from elbow to hip can be calculated by

$$Length_{ElbowToHip} = Length_{Torso} - Length_{UpperArm} \tag{4}$$

shown as *(b-c)* in Figure 4.

3. **Keyboard position:** Affects the angle of the upper arm. We set the keyboard to be 15 cm from the edge of the desk according to ergonomics guidelines [44], and use chair position to make the upper arm vertical.

4. **Chair position:** Once both desk height and keyboard position are determined, the chair position determines the angle of the upper arm. We can calculate the chair position relative to a front-mounted distance sensor such as the Kinect by

$$Distance_{Chair} = Length_{Forearm} + Distance_{Keyboard} \tag{5}$$

where $Distance_{Chair}$ and $Distance_{Keyboard}$ are the relative distances from the chair and keyboard to the Kinect sensor, respectively.

5. **Monitor position:** The height of the monitor affects forward head tilt, and the height and distance together affects the vertical viewing angles. The height can be calculated by adding the chair height and the distance between the head and the hip.

IMPLEMENTATION

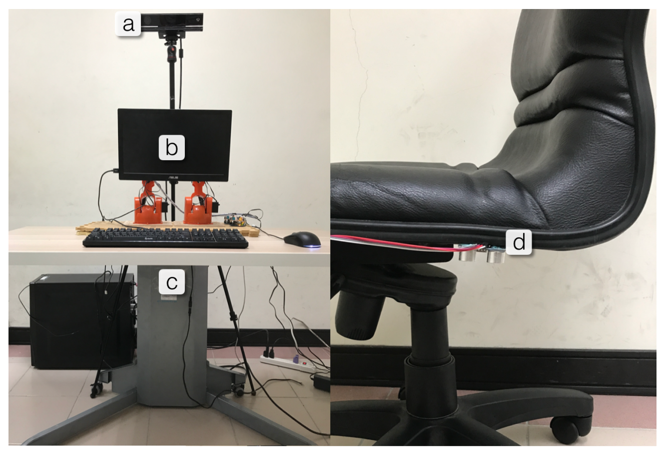

Figure 5. Our prototype system consists of: (a) a Kinect v2 sensor (b) an LCD monitor supported by dual Arduino-based robotic arms, (c) a motorized desk controlled via Arduino, and (d) a chair with an Arduino-based ultrasonic height sensor.

As shown in Figure 5, our prototype uses a Microsoft Kinect v2 sensor for skeleton sensing and posture monitoring with the Kinect Unity SDK on a Windows 10 computer. We placed the Kinect sensor at distances of 130 cm from the floor and 8 cm to the edge of the table, so it can capture the full body skeletal data and also track the head height and sitting distance from the keyboard/desk.

Although the Kinect v2 has been shown to have potential in serving as a reliable clinical measurement tool [28], we discovered that the the 5 key body length measurements from the sensor were too noisy in normal standing, walking, and sitting postures. To improve measurement accuracy, our system asks users to perform two custom postures as shown in Figure 6 for one second each. Since thigh thickness could not be calculated using joints, we used pixel-based measurements [5] using the user's depth sense map from the Kinect. We could then calculate thigh thickness by using the pixel ratio between the thigh thickness and lower leg length, scaled by the known value of the lower leg length.

Using these measurements, the system calculates the proper chair and desk height. The desk height is adjusted with a Conset 501-7 electric standing desk, which we modified to control its height via Arduino by replacing the manual adjustment switch with a circuit with four relays. The operating range of the desk is 66 cm to 118 cm and 50 kg.

Building a motorized chair that can move and adjust height was not trivial, so our current prototype employs distance sensing and real-time visual instructions to guide users in making manual adjustments. The chair height is sensed using an ultrasonic distance sensor via Arduino, and visual instructions to raise/lower the chair are shown on the monitor. The Kinect sensor is used to track the user's sitting distance from the desk/keyboard, and visual instructions to move the chair forward and backward are shown on the monitor.

To build a monitor that can adjust height, tilt, and viewing distance, our prototype uses an ASUS MB169B+ 15.6" portable LCD monitor [1] and Arduino Braccio robotic arms [4]. Due to the weight support limit of the Braccio robotic arms, we combined 2 arms to operate the monitor. The monitor height is calculated by using the Kinect sensor to track the user's head position and the desired viewing angle.

Figure 6. Two custom postures for anthropometric measurement. The white line on the user's thigh indicates the thickness extracted from the user's color map from the Kinect.

EVALUATION

To evaluate the accuracy, speed, and usability of ActiveErgo, we conducted a user study to compare it with the manual approach. We recruited 12 participants (5 females) from students and staff members at a local university. Their heights ranged from 156 cm to 175 cm (mean=167.5, SD=6.8), and their weights ranged from 45 kg to 78 kg (mean=58.6, SD=9.6).

Procedure

We asked users to study the relevant ergonomics guidelines for 5 minutes, making sure that they clearly understood the 6 key posture angles. We also asked users to practice adjusting the chair manually, and to practice using the keyboard input that we provided to adjust the motorized desk and the monitor height via robotic arms.

In the first phase, we asked users to manually adjust the workspace to meet the ergonomics guidelines for the 6 posture angles. The task completion time was calculated when the participant started making the first adjustment, until the participant informed us that the task was complete.

In the second phase, we asked users to use ActiveErgo and follow its visual instructions. The task completion time was calculated when the participant was asked to perform the first posture for Kinect measurement, until the monitor has finished its automated adjustment.

At the end of each phase, we measured the 6 posture angles using the same procedure as describe in our field study, and asked participants to fill out a NASA Task Load Index (NASA-TLX) questionnaire.

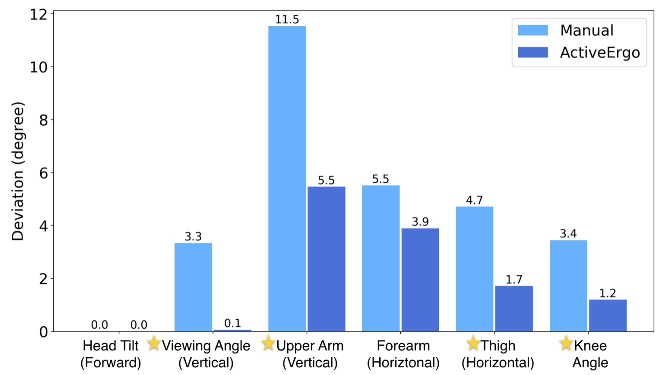

Figure 7. Average deviation from ideal postures as specified by ergonomics guidelines from the 12-person user study.

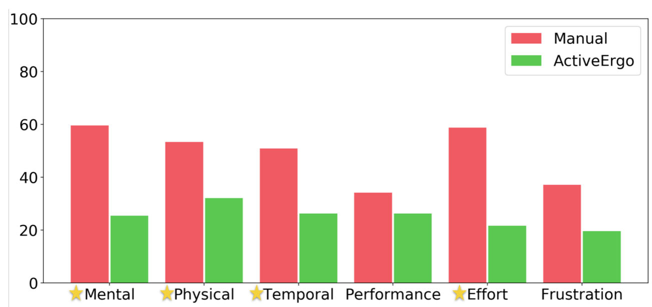

Figure 8. The average NASA-TLX scores from the 12-person user study.

Results

Accuracy

As shown in Figure 7, our prototype system improved overall posture angles by 51.4% compared to the manual approach. ANOVA analysis showed that the reduction of deviation of the following 4 posture angles were statistically significant ($p < .05$): *viewing angle, upper arm, thigh, and knee angle*.

Additionally, 83% of participants using our system were able to meet all 6 posture guidelines to within a 10° margin, compared to just 8.3% for the manual approach.

Speed

Our current prototype used a combination of automatic desk and monitor adjustments and guided manual adjustments of the chair height and position. The average speed of adjustment was 2.2 times faster compared to the manual approach (42.9 s vs. 93.6 s), and the improvement in speed was statistically significant ($p < .05$).

Preference and Workload

All participants preferred ActiveErgo over the manual approach. On a 7-point Likert scale, the average preference rating was 5.8 (SD=0.72) vs. 3.75 (SD=1.22), and the Kruskal-Wallis test showed the difference was statistically significant ($p < .05$).

Figure 8 summarizes the average NASA Task Load Index reported by the participants. The Kruskal-Wallis test indicated significantly lower overall task load for our system (234.17 vs. 151.25, $p < .05$). Among the 6 individual subscales, the task load was significantly lower for our system compared to the manual approach for *Mental, Physical, Temporal, Effort* subscales ($p < .05$).

DISCUSSION

Deviations during Actual Tasks

During our studies, the data for posture angle deviations was collected in a lab-based setting. Although switching in real tasks such as typing, mouse use and browsing would not cause deviations in posture angles due to the same working keyboard and mouse height in our system, we still have noticed that being in a lab-based setting leads to increased self-awareness of maintaining proper postures, and little deviations were derived from proper postures after extended periods of actual tasks. For future work, an extended field study would be needed to observe the deviation from the initial postures. We also envisioned active approaches supporting continuous posture and activity monitoring for helping users maintain ergonomic postures throughout the day.

Clothing Variety

For our evaluation, we did not specify participants on what type of clothes to wear. Our participants during the study all wore fitted clothing such as pants or shorts on their lower body and flat-heeled shoes on their feet. However, loose-fitting clothing such as long dresses and also high heels can affect the accuracy of the body dimension measurements from the Kinect sensor. To accommodate users' wider clothing styles, we are exploring techniques to better infer users' body dimensions from known furniture dimensions, and also expanding our pixel-based measurements to more robustly detect actual joint locations.

FUTURE WORK

Improved Skeletal Sensing and Full Automation

Our vision for ActiveErgo is for a user to walk up to a workspace normally, and have the workspace automatically adjust itself by the time the user sits down. However, there are several technical limitations in our current prototype.

First, our prototype currently requires users to perform two specific postures for the Kinect SDK, in order to provide skeletal measurements that were sufficiently accurate enough for our needs. We are looking into developing custom algorithms that can provide sufficiently accurate measurements based on only normal walking and standing postures.

Second, our prototype still requires manual chair height and position adjustments. While several participants commented that it was too easy to overshoot the chair height adjustment, requiring several back-and-forth adjustment, no participants suggested automatic chair positioning. We are looking at automating chair height adjustment, so that users can simply walk up to the chair and sit down at the proper ergonomic postures.

Activating Postures

Our current system is static in the sense that it stops making adjustments once everything is properly configured. We would like to explore using active furniture to actively encourage users to switch to different postures. For example, raising and lowering the desk periodically to encourage users to switch between standing and sitting.

CONCLUSION

We present ActiveErgo, the first active approach to improve ergonomics by providing automatic and personalized ergonomics through a combination of sensing and self-actuating workspaces. Our user study results demonstrated that our prototype significantly improved users' postures and assisted more users in satisfying ergonomics guidelines. ActiveErgo was also significantly faster (2.2x) than the manual approach, and all participants preferred our system.

ACKNOWLEDGMENT

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REFERENCES

1. ASUS MB169B+ Portable monitor - 15.6" FHD (1920x1080), USB-powered, IPS, Ultra-slim, Auto-rotatable. https://www.asus.com/us/Monitors/MB169BPlus/
2. Digital Protractor with stainless blades 12" front / 14" rear blade. http://www.igaging.com/page21.html
3. Salli AutoSmart. http://salli.com/en/salli-autosmart
4. Tinkerkit Braccio Robot. https://store.arduino.cc/tinkerkit-braccio
5. A. M. S. B. Adikari, N. G. C. Ganegoda, and W. K. I. L. Wanniarachchi. 2017. Non-Contact Human Body Parameter Measurement Based on Kinect Sensor. *IOSR Journal of Computer Engineering* 19, 3 (may 2017), 80–85. DOI:http://dx.doi.org/10.9790/0661-1903028085
6. Myroslav Bachynskyi, Gregorio Palmas, Antti Oulasvirta, Jürgen Steimle, and Tino Weinkauf. 2015. Performance

and Ergonomics of Touch Surfaces: A Comparative Study Using Biomechanical Simulation. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1817–1826.

7. R.A. Bonney and Esmond Nigel Corlett. 2002. Head Posture and Loading of the Cervical Spine. *Applied Ergonomics* 33, 5 (sep 2002), 415–417.
8. Andreas Braun, Sebastian Frank, and Reiner Wichert. 2015. The Capacitive Chair. In *Distributed, Ambient, and Pervasive Interactions*. Springer International Publishing, Cham, Switzerland, 397–407.
9. Carrie Demmans, Sriram Subramanian, and Jon Titus. 2007. Posture Monitoring and Improvement for Laptop Use. In *CHI '07 Extended Abstracts on Human Factors in Computing Systems (CHI EA '07)*. ACM, New York, NY, USA, 2357–2362.
10. Michael Haller, Christoph Richter, Peter Brandl, Sabine Gross, Gerold Schossleitner, Andreas Schrempf, Hideaki Nii, Maki Sugimoto, and Masahiko Inami. 2011. Finding the Right Way for Interrupting People Improving Their Sitting Posture. In *Human-Computer Interaction âĂŞ INTERACT 2011*. Springer Berlin Heidelberg, Berlin, Heidelberg, Germany, 1–17.
11. Holger Harms, Oliver Amft, Gerhard Tröster, Mirjam Appert, Roland Müller, and Andreas Meyer-Heim. 2009. Wearable Therapist: Sensing Garments for Supporting Children Improve Posture. In *Proceedings of the 11th International Conference on Ubiquitous Computing (UbiComp '09)*. ACM, New York, NY, USA, 85–88.
12. Anne Leath Harrison, Theresa Barry-Greb, and Geralyn Wojtowicz. 1996. Clinical Measurement of Head and Shoulder Posture Variables. *Journal of Orthopaedic & Sports Physical Therapy* 23, 6 (jun 1996), 353–361.
13. Jimmy Ho, Reinhard Pointner, Huai-Chun Shih, Yu-Chih Lin, Hsuan-Yu Chen, Wei-Luan Tseng, and Mike Y. Chen. 2015. EyeProtector: Encouraging a Healthy Viewing Distance when Using Smartphones. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '15)*. ACM, New York, NY, USA, 77–85. DOI:http://dx.doi.org/10.1145/2785830.2785836
14. Jeong-Ki Hong, Bon-Chang Koo, So-Ryang Ban, Jun-Dong Cho, and Andrea Bianchi. 2015. BeuPo: A Digital Plant That You Can Raise and Customize with Your Current Posture. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers (UbiComp/ISWC'15 Adjunct)*. ACM, New York, NY, USA, 1015–1020. DOI: http://dx.doi.org/10.1145/2800835.2800953
15. Lumo Bodytech inc. 2011. LUMO LIFT POSTURE COACH. (2011). https://www.lumobodytech.com
16. Institute of Medicine and National Research Council. 2001. *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*. The National Academies Press, Washington, DC, USA.
17. Haruna Ishimatsu and Ryoko Ueoka. 2014. BITAIKA: Development of Self Posture Adjustment System. In *Proceedings of the 5th Augmented Human International Conference (AH '14)*. ACM, New York, NY, USA, 30:1–30:2.
18. Alejandro Jaimes. 2005. Sit Straight (and Tell Me What I Did Today): A Human Posture Alarm and Activity Summarization System. In *Proceedings of the 2Nd ACM Workshop on Continuous Archival and Retrieval of Personal Experiences (CARPE '05)*. ACM, New York, NY, USA, 23–34.
19. Alejandro Jaimes. 2006. Posture and Activity Silhouettes for Self-reporting, Interruption Management, and Attentive Interfaces. In *Proceedings of the 11th International Conference on Intelligent User Interfaces (IUI '06)*. ACM, New York, NY, USA, 24–31.
20. Soonmook Jeong, Taehoun Song, Hyungmin Kim, Miyoung Kang, Keyho Kwon, and Jae Wook Jeon. 2011. *Human Neck's Posture Measurement using a 3-Axis Accelerometer Sensor*. Springer Berlin Heidelberg, Berlin, Heidelberg, 96–109. DOI: http://dx.doi.org/10.1007/978-3-642-21934-4_9
21. Peter T. Katzmarzyk, Timothy S. Church, Cora L. Craig, and Claude Bouchard. 2009. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. *Medicine & Science in Sports & Exercise* 41, 5 (may 2009), 998–1005.
22. Rakhshaan Khan, Ambreen Surti, Rehana Rehman, and Umar Ali. 2012. Knowledge and Practices of Ergonomics in Computer Users. *Journal of the Pakistan Medical Association* 62, 3 (mar 2012), 213–217.
23. Jeong ki Hong, Sunghyun Song, Jundong Cho, and Andrea Bianchi. 2015. Better Posture Awareness Through Flower-Shaped Ambient Avatar. In *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '15)*. ACM, New York, NY, USA, 337–340.
24. Joohee Kim, Na Hyeon Lee, Byung-Chull Bae, and Jun Dong Cho. 2016. Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems. In *A Feedback System for the Prevention of Forward Head Posture in Sedentary Work Environments (DIS '16 Companion)*. ACM, New York, NY, USA, 161–164.
25. T. Määttä, C. W. Chen, A. HÃď rmÃď, and H. Aghajan. 2014. Collaborative vision network for personalized office ergonomics. In *2014 International Conference on Computer Vision Theory and Applications (VISAPP)*, Vol. 2. IEEE, Washington, DC, USA, 403–410.

26. L. Martins, R. Lucena, J. Belo, R. Almeida, C. Quaresma, A. P. Jesus, and P. Vieira. 2014. *Intelligent Chair Sensor – Classification and Correction of Sitting Posture*. Springer International Publishing, Cham, 1489–1492. DOI: http://dx.doi.org/10.1007/978-3-319-00846-2_368

27. Takeshi Oozu, Aki Yamada, Yuki Enzaki, and Hiroo Iwata. 2016. Escaping Chair: Furniture-shaped Device Art. In *ACM SIGGRAPH 2016 Posters (SIGGRAPH '16)*. ACM, New York, NY, USA, 8:1–8:2.

28. Karen Otte, Bastian Kayser, Sebastian Mansow-Model, Julius Verrel, Friedemann Paul, Alexander U. Brandt, and Tanja Schmitz-Hübsch. 2016. Accuracy and Reliability of the Kinect Version 2 for Clinical Measurement of Motor Function. *PLOS ONE* 11, 11 (nov 2016), e0166532. DOI: http://dx.doi.org/10.1371/journal.pone.0166532

29. P. Paliyawan, C. Nukoolkit, and P. Mongkolnam. 2014. Prolonged Sitting Detection for Office Workers Syndrome Prevention using Kinect. In *2014 11th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*. IEEE, Washington, DC, USA, 1–6.

30. Hugo Pereira, Leonardo Martins, Rui Almeida, Bruno Ribeiro, Claudia Quaresma, Adelaide Ferreira, and Pedro Vieira. 2015. System for Posture Evaluation and Correction - Development of a Second Prototype for an Intelligent Chair. In *Proceedings of the International Conference on Biomedical Electronics and Devices - Volume 1: BIODEVICES, (BIOSTEC 2015)*. ScitePress, Setúbal, Portugal, 204–209.

31. Luis Miguel Salvado and Artur Arsenio. 2016. Sleeve Sensing Technologies and Haptic Feedback Patterns for Posture Sensing and Correction. In *Companion Publication of the 21st International Conference on Intelligent User Interfaces (IUI '16 Companion)*. ACM, New York, NY, USA, 74–78.

32. David Sirkin, Brian Mok, Stephen Yang, and Wendy Ju. 2015. Mechanical Ottoman: How Robotic Furniture Offers and Withdraws Support. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI '15)*. ACM, New York, NY, USA, 11–18.

33. W. Song-Lin and C. Rong-Yi. 2010. Human Behavior Recognition Based on Sitting Postures. In *Proceedings of the 2010 International Symposium on Computer, Communication, Control and Automation (3CA)*, Vol. 1. IEEE, Washington, DC, USA, 138–141.

34. Marco Spadafora, Victor Chahuneau, Nikolas Martelaro, David Sirkin, and Wendy Ju. 2016. Designing the Behavior of Interactive Objects. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '16)*. ACM, New York, NY, USA, 70–77.

35. Alexander Sproewitz, Aude Billard, Pierre Dillenbourg, and Auke Jan Ijspeert. 2009. Roombots-mechanical Design of Self-reconfiguring Modular Robots for Adaptive Furniture. In *ICRA '09 IEEE International Conference on Robotics and Automation (ICRA '09)*. IEEE, Washington, DC, USA, 4259–4264.

36. Leon Straker, Robin Burgess-Limerick, Clare Pollock, Kevin J. Murray, Kevin Netto, Jemma Coleman, and Rachel Skoss. 2008. The Impact of Computer Display Height and Desk Design on 3D Posture during Information Technology Work by Young Adults. *Journal of Electromyography and Kinesiology* 18, 2 (apr 2008), 336–349.

37. Ho sub Lee. 2015. Apparatus and Method for Assisting User to Maintain Correct Posture. (2015). http://www.google.com/patents/US9141761

38. Yuichiro Takeuchi and Jean You. 2014. Whirlstools: Kinetic Furniture with Adaptive Affordance. In *Proceedings of the Extended Abstracts of the 32Nd Annual ACM Conference on Human Factors in Computing Systems (CHI EA '14)*. ACM, New York, NY, USA, 1885–1890.

39. Katsuma Tanaka, Shoya Ishimaru, Koichi Kise, Kai Kunze, and Masahiko Inami. 2015. Nekoze!: Monitoring and Detecting Head Posture while Working with Laptop and Mobile Phone. In *2015 9th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '15)*. IEEE, Washington, DC, USA, 237–240.

40. Hidde P. van der Ploeg, Tien Chey, Rosemary J. Korda, Emily Banks, and Adrian Bauman. 2012. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. *Archives of Internal Medicine* 172, 6 (mar 2012), 494–500.

41. Jannique G.Z. van Uffelen, Jason Wong, Josephine Y. Chau, and Wendy J. Brown. 2010. Occupational Sitting and Health Risks: A Systematic Review. *American Journal of Preventive Medicine* 39, 4 (oct 2010), 379–388.

42. Jens Wahlström. 2005. Ergonomics, Musculoskeletal Disorders and Computer Work. *Occupational Medicine* 55, 3 (mar 2005), 168–176.

43. Matthias Wolfel. 2017. Acceptance of Dynamic Feedback to Poor Sitting Habits by Anthropomorphic Objects.

44. Hoi Chi Woo, Peter White, and Christopher Lai. 2015. Ergonomics Standards and Guidelines for Computer Workstation Design and the Impact on Users' Health - A Review. *Ergonomics* 59, 3 (sep 2015), 464–475.

45. S. Yang, B. K. J. Mok, D. Sirkin, H. P. Ive, R. Maheshwari, K. Fischer, and W. Ju. 2015. Experiences developing socially acceptable interactions for a robotic trash barrel. In *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN) (IEEE '15)*. IEEE, Washington, DC, USA, 277–284.

46. Ying Zheng and J. B. Morrell. 2010. A vibrotactile feedback approach to posture guidance. In *2010 IEEE Haptics Symposium*. 351–358. DOI: http://dx.doi.org/10.1109/HAPTIC.2010.5444633