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AUTOMATED PROLONGED SITTING DETECTION IN OFFICE WORKPLACES USING KINECT

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ABSTRACT

Nowadays, prolonged sitting becomes bad ergonomic habit within office workers. While they are too focusing on works, they do not realize this habit can lead to unhealthy lifestyle. This project proposed an algorithm of monitoring system for automated prolonged sitting detection at office workplaces by using Kinect Camera. The skeleton joints obtained from real-time skeleton data of Kinect camera will be analysed in selecting the appropriate skeleton joint coordinates that can represent sitting and standing activities. This was done using the boxplot technique, which can identify the discriminant features of both activities. After that, the prolonged sitting detection system was developed based on the selected skeleton joint. The developed system will give user the real-time feedback of how long they had been sitting and record the sitting time. Analysis of the result revealed that there are 7 out of 20 skeleton joint coordinates can discriminate between sitting and standing with 98.33% accuracy of the developed system.

Keywords: prolonged sitting, Kinect, ergonomic.

1. INTRODUCTION

Ergonomics is very important as it is aim to provide safe and comfortable workspaces and reduce work-related injuries and illness to the workers at their workplaces [1]. According to [2], Ergonomics is the study of laws of works or relationship between people with their work surroundings and it actually can be design of anything involving people such as workspaces, health and safety. Nowadays people worldwide mostly use computer to do their task at workplaces. Chair [3, 4], desktop table and also other workstation [5] environment are designed with good ergonomic in order to fit the workers, protect them from any injury and take care of the bad posture during working. However, they often sit for longer period especially when they are too focusing on works and exposing themselves to the dangerous of prolonged sitting habit. This is not a good example of ergonomics and can cause body pain to them and disrupting their nervous system. It is advisable for people to move their body frequently and take a rest between their working hours. However, due to the workloads, they often forget the effects resulting from prolonged sitting. That is why the monitoring need to be done to ensure that the people keep alerting with their sitting posture and prompted if there is any unhealthy sitting pattern is detected.

As image processing technologies is growing in health industries, there are many camera-based system developed for health-monitoring system. Kinect camera is one of the trend used in health-related research such as head detection for fall detection [6], recognise the human gesture [7, 8], and other health application. Kinect camera is one of those technologies that is believed can be used to monitor sitting position effectively. Kinect has many potential as its advantage [9] is comparable to other existing 3D motion capture system available in the market. As mentioned in the background study, ergonomic is important in providing a good environment and reducing work-related injuries at the workplaces. People design a good chair to provide good ergonomics to human body while sitting. However, it is still not enough when prolonged sitting became the habit. Prolonged sitting is a kind of bad ergonomic that nowadays many people not realize that they practice it. Prolonged sitting has many bad effects to health such as getting back pain, increase the probability of cardiovascular mortality, and musculoskeletal disorder. Thus, the prolonged sitting need to be monitored continuously to ensure that people aware of how long they sit at their workplaces. Kinect is a low cost sensor that is capable in used to monitor human activities and body movement. However, little study [10] has been done in utilizing the Kinect to monitor and detect prolonged sitting. Moreover, most of the previous works focused only on correcting sitting posture but not on monitoring the prolonged sitting habit. Therefore, an automated system to detect prolonged sitting based on Kinect sensor has been proposed in this project. This system will obtain the skeleton joint coordinates, and detect the sitting activities as well as record the sitting time.

2. LITERATURE REVIEW

The previous works related to this study is fragmented into the existing technologies for ergonomics and prolonged sitting which is presented in Section 2.1 while the existing application on Kinect sensor is described in Section 2.2.

2.1 Ergonomics and prolonged sitting

Ergonomics is the scientific discipline of designing the workstation that can fit the human limitations and capabilities with their working environment [8]. Understanding the ergonomics of office seating and applying them properly is essential in order to provide a safe working environments and product better work. This is because most of the office work is mainly performed from a seated position [9]. Ergonomic risk factors such as high forceful exertion, high repetition of works and awkward postures can lead to musculoskeletal disorder. Prolonged sitting is one of the examples of bad ergonomics practice. Office worker is one of largest single occupational group [11] that has high risk exposing to prolonged sitting based on their occupational prolonged sitting period is found everywhere. Sitting keeps our upper body stable, however, sitting for longer time can make us discomfort. This is what happened almost to the office workers. Numerous experiments have established that prolonged sitting can lead to many health risks[12, 13]. Sedentary actions during sitting can give impact to low back and suffer from strained neck. Study in [14] found that workers who were sitting for more than 95% of the working time have increased the risk of getting neck pain. Moreover, prolonged sitting also can increase the risk of heart attack which can increase the probability for individual to get cardiovascular mortality [15]. Too much sitting also can give higher chance for someone to get obesity, metabolism syndrome and high blood sugar, cancer and may lead to death. New research findings found that breaking up the sitting time is necessary as it can lower the postprandial glucose, insulin response [16] and resting blood pressure[17]. Prolonged sitting can also cause musculoskeletal disorders which well-known in affecting the worker health and productivity[18]. According to Bureau of Labour Statistics (BLS), there are about 387820 musculoskeletal disorders cases are being reported which contribute about 33% of all injury and illness of workers in 2011. It is necessary to reduce the time of sitting as it is not good for health in a long term. In ergonomics, there are several different opinions for practising a good sitting habit. Stanford University Environmental Health and Safety [19] suggests take a short breaks about two minutes every maximum 30 minutes of continuous computer usage and repetitive action such as laboratory tasks or one minute every 10 minutes to rest the body. While State Fund CA [20] recommends to take rests for 10 to 15 seconds every 10 minutes or 3 to 5 minutes every 30 minutes to 1 hour to able the body getting some rest.

Even though the people aware about the knowledge of ergonomics practice, however, it would still not be effective unless the appropriate equipment which able to force the people to do such practice is implemented [21]. Work intervention is also another way to reduce the prolonged sitting habit. Study in [22] introduced the take-a-stand project to reduce the sitting period which succeed in improving the upper back and neck pain as well as various mood states. While investigation in [23] proposed an animation program to promote healthy computer usage by remind the users of getting rest and do the light activities. Thus it is important to have an ergonomic training as well as appropriate equipment which able to force the people to practice this good ergonomic.

2.2 KINECT sensor

Kinect camera is powered by hardware and software and become one of the choice for health monitoring research. This natural interaction device is a human motion tracking which is added to Xbox 360 has 640x480-pixel resolution with 32 bit RGB resolution running at 30 frames per second. Kinect consists of three main components [24]:

- Colour VGA video camera which detects three colour components; red, green and blue for facial recognition and other detection features.
- 3D-Depth sensor which functioned to detect the room in 3D.
- Multi-array microphone to detect the voice command and isolate the player voice and noise in the surrounding.

The skeleton tracking is designed to track the human movement while facing the sensor thus it is quite challenging for detecting the part of users where is not visible to the Kinect sensor [25]. Kinect is capable to track as many as 20 joints position, 10 joints position during standing and 10 joints position during sitting. Each of the joints position represented by its 3D coordinates. Figure-1 shows the 20 joints positions that are shown on Kinect sensor (spine, hips, knees, ankles, feet, elbows, shoulders, wrists, arms and head):

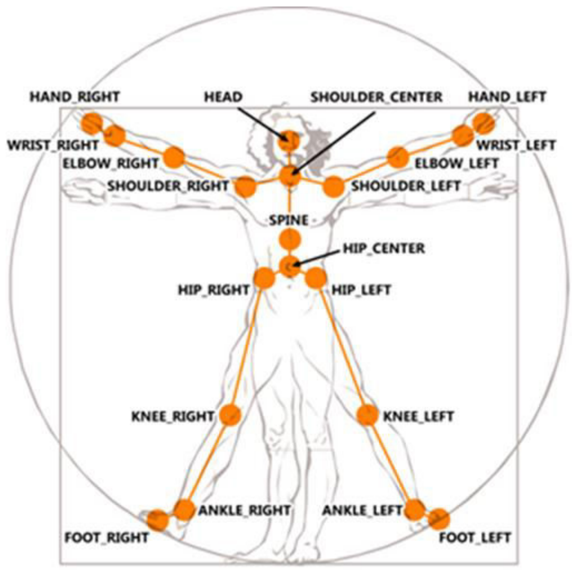

Figure-1. 20 skeletal joints for skeletal data (adapted from [25]).

Initially, Kinect was designed as a controller for the Microsoft Xbox game console. Due to its controller-free characteristic, the Kinect is not limited to gaming purposes alone. This sensor has the potential to be implemented in several non-invasive human-computer interaction (HCI) based application. For example, study in [6] introduced a fall detection system that based on head position using Kinect depth sensor. Histogram of Oriented-Gradient was computed to locate the head and

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shoulder before detecting a fall based on vertical speed of the head contour and the head-ground distance.

As for gesture recognition, investigation in [8] used Kinect sensor to recognize the gesture from Indian Classical Dance. By using Support Vector Machine (SVM) as the classifier, only eleven joint coordinates were required to distinguish several different emotions such as anger, sadness, happiness, fear and relaxation. The features were extracted according to the distance between the different parts of the upper human body, velocity and acceleration produced also the angle between the joints. While study in [7] used Kinect to evaluate the performance of several different classification methods such as back propagation neural network, support vector machine, decision tree and naïve bayes in recognizing the human gesture.

Therefore, Kinect sensor for prolonged sitting detection and monitoring among office worker has been proposed in this project since Kinect has a potential to be implemented in proposed system. Moreover, Kinect has been promised to be comparable with other existing 3D motion capture system with several advantages such as low-cost, portable, accurate depth information, fat 3D information and high frame-rate [9].

3. MATERIALS AND METHODS

The research design was conducted as shown in the following Figure-2:

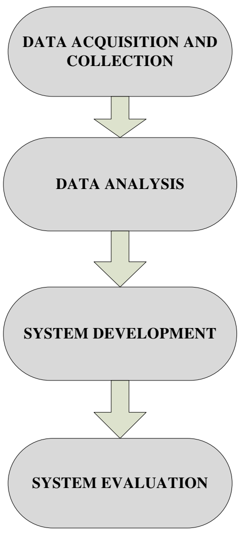

Figure-2. Research process.

3.1 DATA ACQUISITION AND COLLECTION

As mentioned before, Kinect can detect depth, colour and skeletal. For data acquisition and collection, this project was focused on obtaining the skeletal joints of the 10 subjects performing the sitting and standing activities as shown in Figure-4. Each subject per activity consists of 150 frames of skeleton joint coordinates. Thus there were total of 3000 skeleton data that was collected in this project. The skeletal joints obtained in matrix form which are in x, y and z coordinates. These coordinates were saved in excel format along with the frame images, arranged and organized before proceeding to the data analysis. Figure-3 shows the recommended experimental setup whereby the Kinect was tilted -18° located at 40° relative to the line of sight of the user with distance of one meter from the user before skeleton data is obtained.

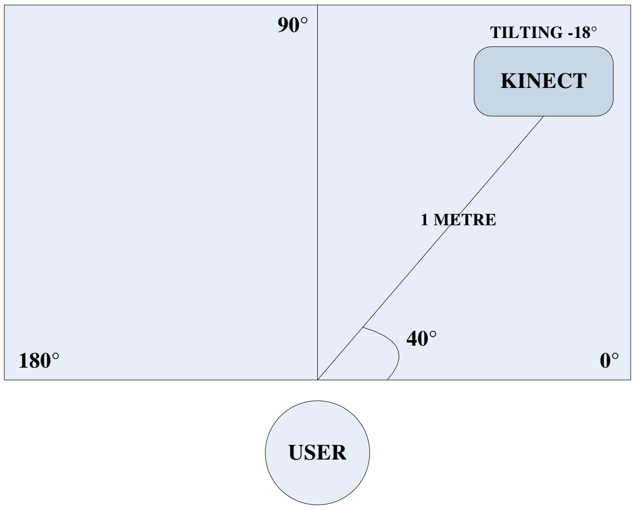

Figure-3. The recommended experimental setup.

Figure-4. Data acquisition and collection for standing and sitting activities.

3.2 Data analysis

After that, data had been arranged and organized, all the data were analysed by using the boxplot technique. Boxplot technique is a technique that is used to visualize the 5-number summary which are minimum value, lower quartile, median, upper quartile and maximum value of the dataset [26]. It also shows the distribution of the data in a fast way which can also summarize the statistic in more straightforward way. In this project, box plot was used in selecting the appropriate skeleton joint coordinates that can discriminant between standing and standing activities. By using boxplot technique, skeleton joint coordinate that were giving the most contribution in differentiate between sitting and standing can be clearly identify. The selected skeleton joints were then used as the features representing the sitting and standing activities for developing the system in next process.

3.3 System development

In system development, there were two stages involved which were the calibration stage and the main system stage. The purpose of the calibration stage is to capture the user's image in sitting position and obtain the threshold data that can differentiate between sitting and standing activities that will be used by the main program. The flowchart of the calibration stage is shown in Figure-5.

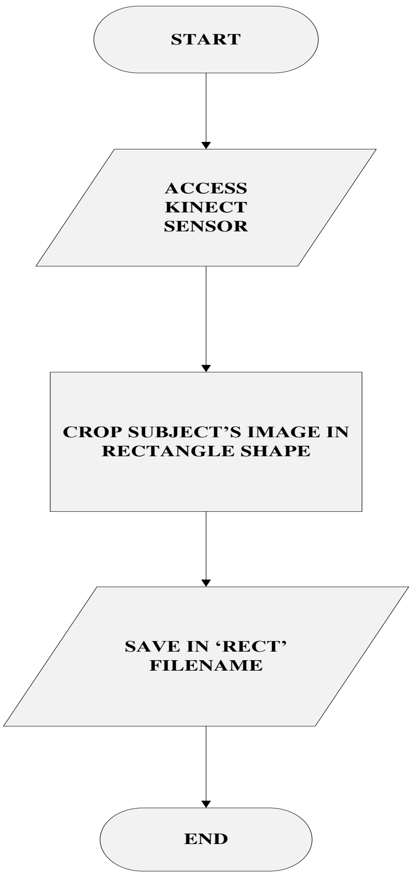

Figure-5. The calibration stage flowchart.

Once the Kinect sensor had been accessed, it showed 640x480 dimension of screen resolution. The subject was required to sit still, subject image was captured and the sitting activity was cropped from the obtained image. The cropping should not be too large or too small because it will affect the accuracy of the system to detect the activities of sitting or standing. From cropping process, the threshold data in form of rectangle (rect) coordinates was obtained. Then, this data was saved and will be used for the main system. The flowchart of the main system stage is shown in Figure-6.

In the main system, this is the stage where the activities will be detected by the Kinect camera. Once the subject appeared in the Kinect camera, the skeleton was tracked by the Kinect sensor and eventually the twenty skeleton joints was plotted on the subject's body. By using the threshold data from the previous stage that had been saved before as reference, if J or above number of selected skeleton joints indicating sitting was detected or appeared inside the cropped box (created using threshold data), the system displayed 'sitting' on the screen. Once the subject was standing, the screen will display 'stand' and the previous sitting time recorded. Figure-7 shows the main system program.

3.4 System evaluation

The proposed system was evaluated using another 10 subjects in order to obtain the performance of the system in terms of accuracy in detecting the sitting and standing activities. The accuracy was calculate based on number of correct activities detected done in total number of 60 activities between sitting and standing simultaneously that had been done by all the subjects. The accuracy is formulate as:

$$\frac{\textbf{Number of correct activities detected}}{\textbf{Total number of activities}} \times (\mathbf{100}\%) \qquad (3.1)$$

4. RESULTS

In this chapter, the result from data analysis based on box plot is presented in Section 3.1 while the proposed system performance is displayed in Section 3.2

4.1 Data analysis result

As mentioned earlier, Kinect can detect up to 20 skeleton joints coordinate position. However, we only used first 10 joint coordinates that can represent sitting which can be seen in Table-1. This is because the other 10 joints coordinates were not static, keep moving, unstable and cannot provide the enough information while the subject was performing the sitting and standing activities.

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Table-1. Skeleton joints coordinate indication (Mathworks).

Number indication	Position on the body
1	Hip centre
2	Spine
3	Centre of shoulder
4	Head
5	Left shoulder
6	Left elbow
7	Left wrist
8	Left hand
9	Right shoulder
10	Right elbow
11	Right wrist
12	Right hand
13	Left hip
14	Left knee
15	Left ankle
16	Left foot
17	Right hip
18	Right knee
19	Right ankle
20	Right foot

For the data analysis, boxplot technique was used to identify which joints represent the sitting activities and identify the discriminant features since the technique are simple and can be used for visual representation of large distribution data. Figures 8 and 9 show the joint coordinates of the aforementioned 10 subject performing the sitting and standing activities in form of x- and y-coordinates. Overall, it seem that most of the y-coordinate joints were not overlap to each other in representing sitting and standing activities while x-coordinate were slightly overlap. Based on observation, there are 7 joints that were identified as a good feature in representing the sitting and standing activities. The 7 joints are no 1, 2, 3, 4, 5, 9 and 10 which seem clearly separate between standing and sitting activities especially in y-coordinate joints.

Furthermore, the outliers which are the value that far from central value are also not distribute much, not too far away from the central values and slightly overlap between two boxes that represent the sitting and standing.

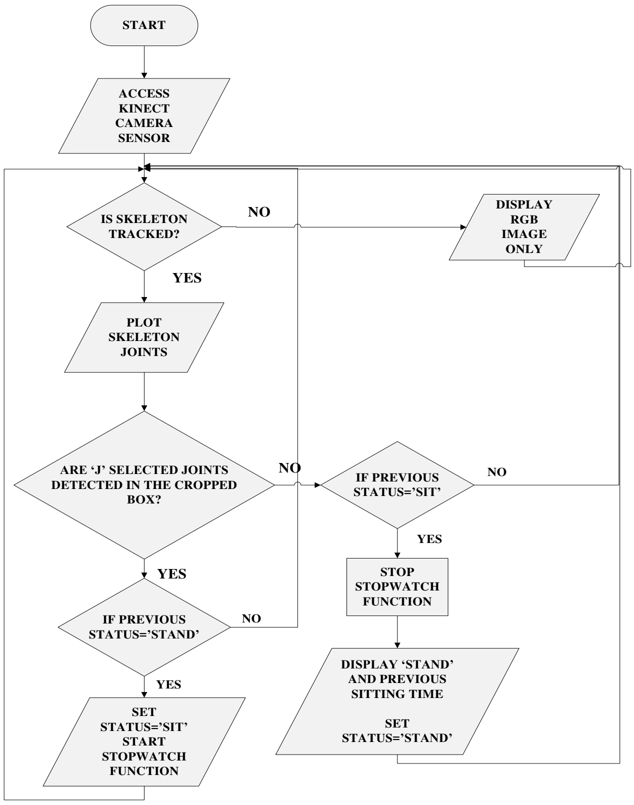

Figure-6. The main system flowchart.

Figure-7. Main system program of system development.

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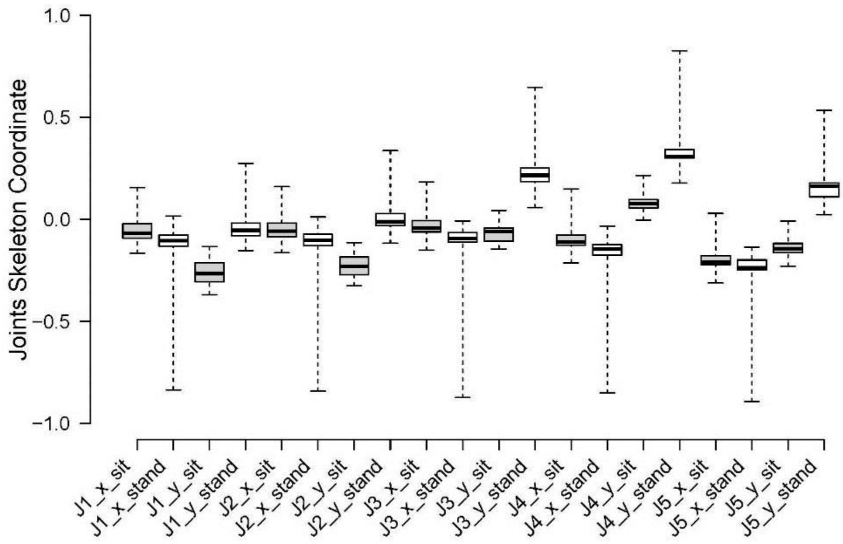

Figure-8. Joints 1 until joints 5 between sitting and standing.

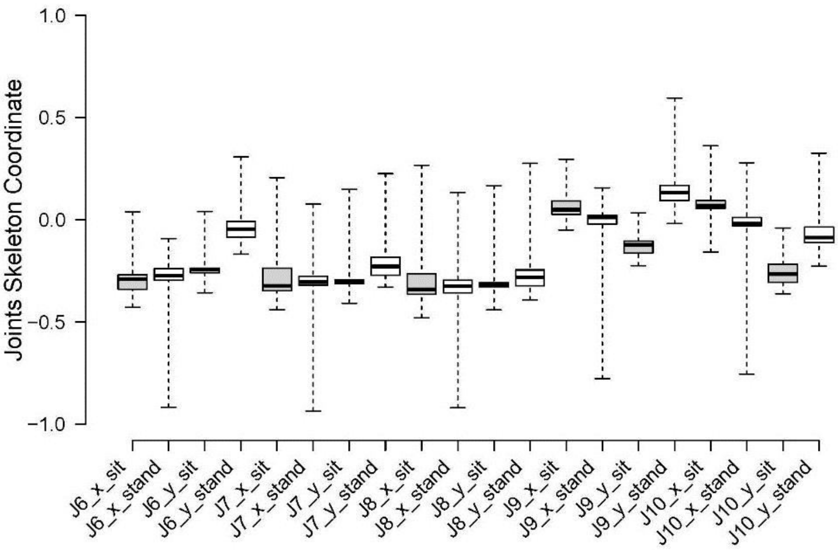

Figure-9. Joint 6 until joint 10 between sitting and standing.

4.2 System performance

This system performance in term of accuracy was done by tested the developed system to another 10 subjects. Since the number of selected skeleton joint obtained from Section 3.1 is 7, sitting is detected if all 7 skeleton joint are inside the cropped rectangle (threshold data). In evaluating the system performance, 4 different cases were simulated by varying J number of selected joint or above that are inside the cropped rectangle (see Table-2). Every subject need to perform stand and sit simultaneously for 3 times. Thus, the total activities done by each subject is 6 activities. Based on (3.1), the accuracy was calculated based on number of correct activities detected done in total number of 60 activities between sitting and standing simultaneously.

Table-2. Cases and the condition.

Case	The number of selected skeleton joints inside the cropped rectangle, J or above
1	3
2	4
3	5
4	6

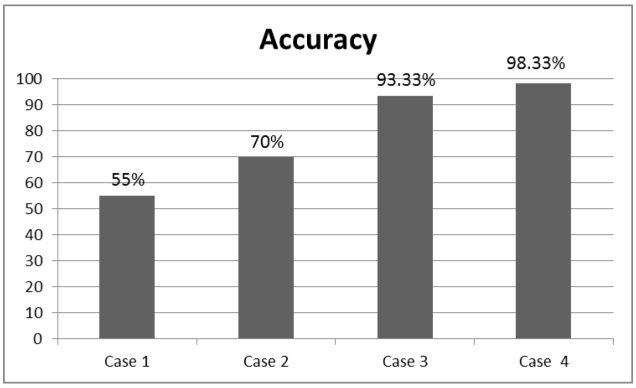

Figure-10. The performance of the system in different cases.

As can be seen in the Figure-10, the highest accuracy is achieved when the joints detected inside the cropped box are more than 6 skeleton joints coordinate with 98.33% compare to more than 5 (93.33%), more than 4 (70.00%) and followed by more than 3 with only 55.00%. This might be due to the less descriptive data given by small number of skeleton joints used sitting. Moreover, the large number of skeleton data that need to position inside the cropped rectangle might also provide the strict condition or strict rule for the developed algorithm in deciding between the sitting and standing activities.

5. CONCLUSION AND FUTURE WORK

In the nutshell, the features obtained from Kinect skeleton tracker of office worker has been analysed using boxplot technique to identify which joints that represent the sitting and differentiate between sitting and standing activities. The skeleton joints coordinates that had been selected are hip centre, spine, centre of shoulder, head, left shoulder, right shoulder and right elbow.The accuracy of the system is also increased when the number of skeleton joints detected inside the cropped box is large. Therefore, the development system can detect the prolonged sitting of the users in office workplaces by obtaining the skeleton joint coordinates; and detect the sitting activities as well as record the sitting time.

This study could eventually lead to the development of prompting system that could alert the office workers if they perform the prolonged sitting which can consider as one of the common bad ergonomic habit. Moreover, this work has potential in preventing the worker practice the bad sitting posture if such system can be integrated with the sitting posture monitoring system.

REFERENCES

[1] (16th September). Dohrmann Consulting. Available: http://www.ergonomics.com.au/what-is-ergonomics/.

[2] D. S. Bloswick and T. Villnave. 2001. Ergonomics. in Patty's Industrial Hygiene, ed: John Wiley & Sons, Inc.

[3] A. M. Brintrup, J. Ramsden, H. Takagi, and A. Tiwari. 2008. Ergonomic Chair Design by Fusing Qualitative and Quantitative Criteria Using Interactive Genetic Algorithms. Evolutionary Computation, IEEE Transactions on. 12: 343-354.

[4] A. A. M. Faudzi and K. Suzumori. 2011. Stiffness and viscous coefficient characteristics for ergonomics chair design. Advanced Intelligent Mechatronics (AIM), 2011 IEEE/ASME International Conference on. pp. 661-666.

[5] P. a. S. Services. 2004, 18th October 2015. Computer Ergonomics: Workstation layout and lighting. Available: www.labour.gov.on.ca.

[6] N. Anh Tuan, E. Auvinet and J. Meunier. 2012. Head detection using Kinect camera and its application to fall detection. Information Science, Signal Processing and their Applications (ISSPA), 2012 11th International Conference on. pp. 164-169.

[7] O. Patsadu, C. Nukoolkit, and B. Watanapa. 2012. Human gesture recognition using Kinect camera. Computer Science and Software Engineering (JCSSE), 2012 International Joint Conference on. pp. 28-32.

[8] S. Saha, S. Ghosh, A. Konar, and A. K. Nagar. 2013. Gesture Recognition from Indian Classical Dance Using Kinect Sensor. Computational Intelligence, Communication Systems and Networks (CICSyN), 2013 Fifth International Conference on. pp. 3-8.

[9] A. B.-S. Hsu-Huei Wu. Advantages of using a Kinect Camera in various applications. Electrical and computer Engineering, University of Canterbury, New Zealand.

[10] P. Paliyawan, C. Nukoolkit, and P. Mongkolnam. 2014. Prolonged sitting detection for office workers syndrome prevention using kinect. Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2014 11th International Conference on. pp. 1-6.

[11] L. S. Healy GN, Thorp A, Neuhaus M, Robson EL, Owen N and Dunstan DW. 2012. Reducing prolonged sitting in the workplace (An evidence review: full report). Victorian Health Promotion Foundation, Melbourne, Australia.

[12] J. A. Levine. (2015, 18th September). Mayo Clinic. Available: http://www.mayoclinic.org/healthy-lifestyle/adult-health/expert-answers/sitting/faq-20058005.

[13] M. Leung. 2015. CTV News: Health. Available: http://www.ctvnews.ca/health/sitting-for-prolonged-periods-increases-risk-of-death-disease-study-1.2196067.

[14] G. A. M. Ariëns, P. M. Bongers, M. Douwes, M. C. Miedema, W. E. Hoogendoorn, G. van der Wal, L. M. Bouter and W. van Mechelen. 2001. Are neck flexion, neck rotation, and sitting at work risk factors for neck pain? Results of a prospective cohort study. Occupational and Environmental Medicine. 58: 200-207.

[15] W. Taylor. 2011. Prolonged Sitting and the Risk of Cardiovascular Disease and Mortality. Current Cardiovascular Risk Reports. 5: 350-357.

[16] D. W. Dunstan, *et al.* 2012. Breaking Up Prolonged Sitting Reduces Postprandial Glucose and Insulin Responses. Diabetes Care. 35: 976-983.

[17] R. N. Larsen, B. A. Kingwell, P. Sethi, E. Cerin, N. Owen and D. W. Dunstan. 2014. Breaking up prolonged sitting reduces resting blood pressure in overweight/obese adults. Nutrition, Metabolism and Cardiovascular Diseases. 24: 976-982.

[18] N. M. Nur and S. Z. M. Dawal. 2009. Upper limb and lower back muscle activity during prolonged sitting. Science and Technology for Humanity (TIC-STH), 2009 IEEE Toronto International Conference. pp. 234-238.

[19] S. E. H. a. Safety. Work Breaks, Exercises and Stretches [Online]. Available: http://web.stanford.edu/dept/EHS/prod/general/ergo/microbreaks.html.

[20] S. F. CA. Ergonomic Breaks, Rest Periods, and Stretches [Online]. Available: http://www.statefundca.com/Home/StaticIndex?id=http://content.statefundca.com//safety/safetymeeting/SafetyMeetingArticle.aspx?ArticleID=357.

[21] N. Mahmud, D. T. Kenny, R. Md Zein, and S. N. Hassan. 2011. Ergonomic Training Reduces Musculoskeletal Disorders among Office Workers: Results from the 6-Month Follow-Up. The Malaysian journal of medical sciences: MJMS. 18: 16-26.

[22] P. A. S. K. Nicolaas P. Pronk, PhD; Marcia Lowry, MS; Jane Rodmyre Payfer. 2011. Reducing Occupational Sitting Time and Improving Worker Health: The Take-a-Stand Project. Preventing Chronic Disease. 9:110323: pp.

[23] S. C. Wang, C. Jiang, and J. Y. Chern. 2014. Promoting healthy computer use: timing-informed computer health animations for prolonged sitting computer users. Behaviour and Information Technology. 33: 294-300.

[24] C. Stephanie. (2010, 14th October). How Microsof Kinect Works. Available: http://electronics.howstuffworks.com/microsoft-kinect2.htm.

[25] Microsoft. (21st September). The Microsoft Developer Network. Available: https://msdn.microsoft.com/.

[26] M. Spitzer, J. Wildenhain, J. Rappsilber, and M. Tyers. 2014. BoxPlotR: a web tool for generation of box plots. Nat Meth. 11: 121-122.