

Development of Computer Aided Posture Analysis for Rapid Upper Limb Assessment with Ranged Camera

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ABSTRACT

Computer workstation usage leads to health risks, including the development of poor ergonomics in the office. This study investigates the reliability of a ranged camera for posture analysis based on Rapid Upper Limb Assessment (RULA). The cameras were tested under three settings of camera positions. The results show that the side position is the most accurate with the help of calibration and markers. Experts reviewed the advantages of RULA Eye over other assessment tools.

KEYWORDS

RULA; Ranged Camera; Posture Analysis; Upper Limb Discomfort

INTRODUCTION

Computer workstation use has been increasing to 505,254 users, 23.5% of whom are using computer workstations at business establishments. The frequency of use is 99.2% at least once a week (National Statistical Office Thailand, 2012). The growth of computer workstation use is associated with an increase in Work Related Musculoskeletal Disorder (WMSDs) (e.g., Titiranonda et al., 1999; Katz et al., 2000). Many epidemiological studies of office workers have shown the “poor” ergonomics involved in office work (Joines and Sommerich, 2001). Such evaluations can provide essential insight for workstation improvement. Computer workstation assessment can be a challenge for companies with large numbers of employees working in office settings. Moreover, evaluations can pose problems for employers who lack in-house ergonomists. Several ergonomics assessment hardware options require sophisticated setups and are only available at high costs. For example, Motion Analysis requires more than one high-speed camera. Other tools, like gyroscopes and accelerometer sensors, can be used to measure the kinematics of body segments (Luinge & Veltink, 2005). However, those tools can be intrusive and make subjects feel uncomfortable. The Microsoft Kinect™ range camera is a tool that is used to monitor the posture of office workers. Assessment with this tool can pose a challenge for companies with large numbers of employees working in office settings. Developing the tool and establishing techniques for accurately measuring those workstations result in benefits, including freeing the expert so that she/he can perform tasks and analyses that require her/his expertise. Nevertheless, the Kinect is not accurate enough to work well across all situations, such as in dimly lit rooms or while the user is within six feet of the device. In the study by Mentiplay et. al (2013), the reliability and validity of the Kinect for evaluating static foot posture was investigated. Their results show that the majority of foot postures derived using the Kinect were more reliable than traditional visual assessments achieved using the Foot Posture Index, and were valid when compared to a 3D motion analysis system. Its features are extremely useful for clinicians and therapists who seek to assess the performance of their patients (Chang et al., 2012). The Kinect can carry out competitive motion tracking as a marker-based system. An inexpensive and widely available imaging system, the Kinect may possess the characteristics to objectively evaluate body posture in office settings with high accuracy. The aim of this study is to assess the reliability of this system for assessing sitting posture.

Literature Review

Several survey methods are used in office safety industries, such as the Rapid Upper Limb Assessment (RULA) (McAtamney & Nigel Corlett, 1993), the Rapid Entire Body Assessment (REBA), and the Rapid Office Strain Assessment (ROSA) (Sonne et al., 2012). RULA has undergone initial validation, and is widely used for testing computer workstations, for instance, RULA for computer use (Lueder, 1996), computer mouse users (Cook et al., 2000), and children’s computing posture (Dockrell et al., 2002). It has been used to evaluate the level of ergonomic risk by observation of participants’ posture while they were working. The survey instrument was produced by a special combination table of risk scores from the upper arms, lower arms, wrists, neck, trunk and legs. A safety officer takes a RULA checklist form and uses visual inspection to determine posture angles at computer workstations. A grand score is generated, ranging from 1(low) to 7 (high). A score of 1 or 2 is acceptable, a 3 or 4 indicate that changes are required, 5 and 6 requires investigation soon, and a score of 7 requires changes immediately. When using RULA, only the right or left side is assessed at one time (McAtamney & Nigel Corlett, 1993). It may be obvious that observer cannot observe both sides simultaneously.

This method only allows for looking at either one point in time or at worst-case postures. Furthermore, observers must be trained to undertake visual assessment. Several software tools have been designed to facilitate off-line and on-line calculations, such as ErgoIntelligence™ (NexGen Ergonomics, 2014) and Osmond Ergonomics (Osmond Group Limited, 2014). These programs provide checklist images of postures at different angles. The RULA tool is useful for calculation, but it still requires observers to measure the posture angles by themselves. As a result, the ranged camera has an advantage over the manual checklist. The ranged camera and assessment tools have been studied in different conditions. For example, Haggage et al., (2013) studied the ranged camera and RULA for assembly operations. In the same way, the ranged camera has been used for other ergonomics assessments. Sounity et al., (2012) used the ranged camera for NIOSH, and Horejsi et al., (2013) applied the ranged camera to OWAS analysis. None of these studies have presented how the ranged camera might be appropriate for ergonomic analysis. For this research, investigators prioritized the development of RULA and a ranged camera named RULA Eye. The software tool was designed to facilitate visual analysis of the left and right sides of the body by calculating angles from the human skeleton and recording data as data logger.

Objectives

The goal of this research is to create a computerized system for monitoring postures accurately for safety officers.

Our objectives are as follows:

- 1) To determine the possibility of using ranged cameras in conjunction with RULA assessment for data collection and analysis;
- 2) To produce an acceptable level of accuracy for the measuring tool and to find out the best position or viewpoint for both monitoring and calibrating the range camera; and
- 3) To compare RULA Eye (automatic assessment and ranged camera) with a paper based assessment and NexGen (checklist software).

METHODS

The process of working with the tool began by calculating joint angles with the ranged camera. The tool was then implemented with the Visual C# program. The pilot test was set up to identify problems with the existing ranged camera. The final experiment featured the test of the camera with three settings, paired with the posture angles from RULA. At the end, experts reviewed the RULA Eye and compared it with the existing assessment tools.

RULA Eye – Algorithm

The ranged data used for this study was collected with a Kinect™ Xbox 360. The joint angles were calculated using vectors depending on the location of each joint corresponding to its pivot joint's location. Angles were calculated by using a unit vector of two vectors.

$$A = J_o - J_p = (X_o, Y_o) - (X_p, Y_p) \quad (1)$$

$$C = J_a - J_p = (X_a, Y_a) - (X_p, Y_p) \quad (2)$$

$$A \cdot C = \|A\| \|C\| \cos \theta \quad (3)$$

$$\theta = \cos^{-1} A \cdot C / \|A\| \|C\|$$

(1) and (2) are coordinates of body parts – pivots and axis points respectively. The dot product is used to calculate the angle of two Euclidean units, vector A and C in three dimensions (3).

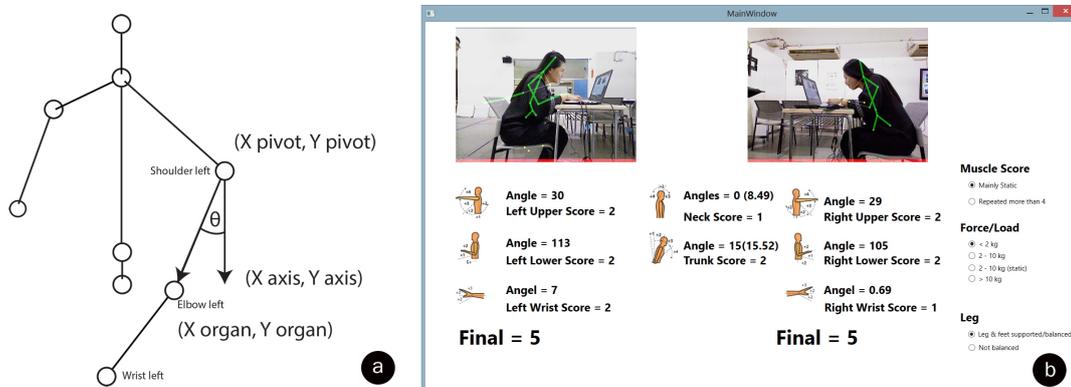


Figure 1. a) Human skeleton, angle and pivots b) RULA Eye

The software interface (see Figure 1) is a visualization of the assessment in real-time with the final score of both the left and right sides of the human body from two cameras. The skeleton lines were overlaid on the subject. For the parts that cannot be observed by cameras, such as muscle scores, force/load and legs, a checklist of options was provided.

Pilot Test

The pilot test was completed with one ranged camera to check performance of equipment by using the processing program with Microsoft Kinect™ SDK v 1.7. The procedure was as follows: 1) Initializing the RULA tables; 2) Starting the timer; 3) Using the skeleton tracking; 4) Calculating the joint angle every 10 seconds; 5) Calculating the RULA assessment every 30 seconds; 6) Recording the RULA scores. The results from the testing gave us clues about the inaccuracies. First, the subject's body was obstructed by the equipment in the workstation, such as the table and notebooks. The camera that faced to the front of subjects could not detect the skeleton, since the monitor blocked the camera's view. Second, the ranged camera could not capture body parts that were blocked by bigger body parts; for example, the leg or hand was blocked by the trunk and calf. Third, the ranged camera could not track on the wrist perfectly. As a result, image processing with ball markers was used on the wrist instead.

Camera location testing

The camera was placed in three locations. First, the camera was placed on both sides of a subject (Figure 2A). Second, two cameras were placed 45 degrees in front of the subject (Figure 2B). Third, both cameras were placed 45 degrees to the back of subject (Figure 2C). The distance between the cameras and table is 145 cm to the centerline of the notebook. Subjects were asked to attach the goniometer with the bubble level for each joint in order to compare with data from the RULA Eye. The camera was set at 45 degrees to avoid blocking the view. The lighting conditions were 300-500 lux.

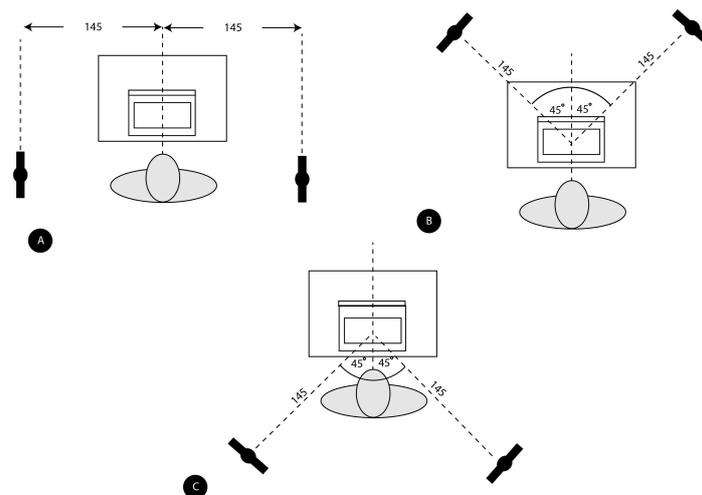


Figure 2. Three locations of the camera

Expert evaluation

Experts reviewed the trials of the paper-based RULA, ErgoIntelligence and RULA eye. The paper-based RULA is an original tool designed by McAtamney and Nigel Corlett (1993). ErgoIntelligence is checklist software that facilitates RULA score calculations. Experts included thirteen safety officers and ergonomists who work in the field of ergonomics or as occupational therapists (mean length of experience: 11 years, SD 10.9). Six of them were male. They had average experience with RULA (mean length of experience: 3.8 years, SD 4.4).

RESULTS

Reliability of ranged camera

The data from the side camera was accurate for many posture positions, such as left and right upper arm and lower arm (see Figure 3). The tolerance of error was not more than 15 degrees. The neck and trunk parts needed to be calibrated while the wrist required ball markers. Without the calibration and markers, the data was far from expected values. These results are similar to the research findings of Haggag et al., (2014).

When both cameras were placed in front, the posture of the left and right upper arms was not accurate between

20 and 60 degrees (see Figure 4). Inaccurate data was recorded from 6 to 37 degrees. This was also true for other parts of the body, like the neck and trunk, which were 7.2 to 16 degrees and 6 to 20.1 degrees for non-calibration respectively. The calibration data improved in accuracy but was still unpredictable. When using the marker on the wrist, the data was more accurate than when the marker was not used.

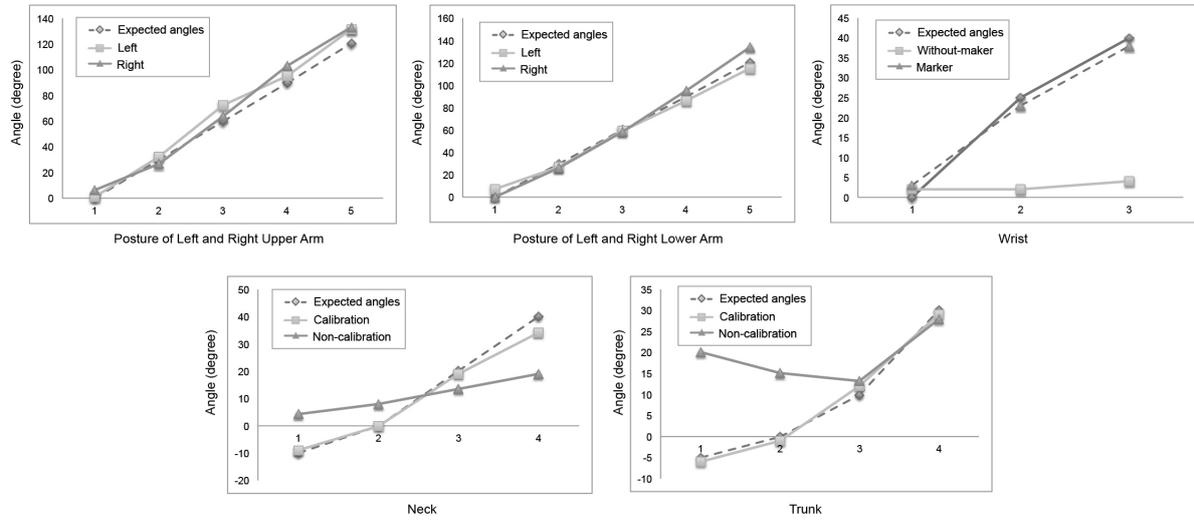


Figure 3. Setting A - side camera

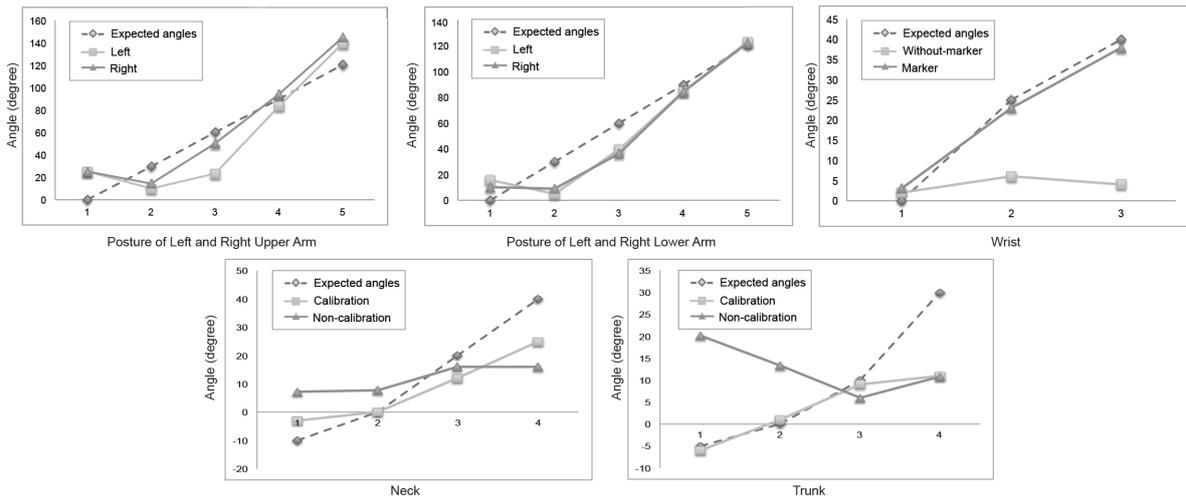


Figure 4. Setting B - front camera

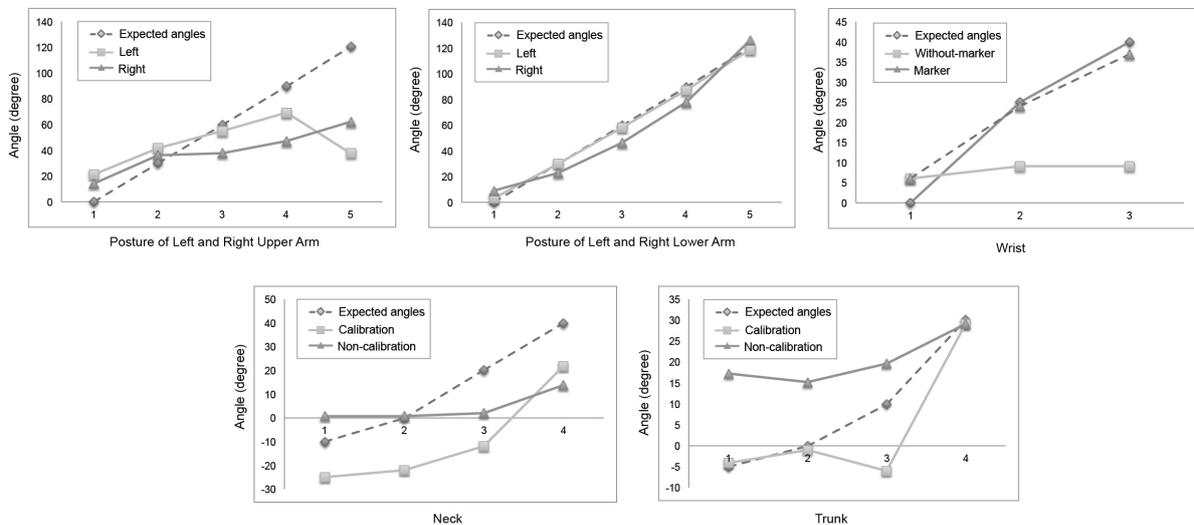


Figure 5. Setting C - back camera

The location of the back camera was accurate on the left and right lower arms. For the neck, trunk and upper arms, the data was far from the expected angles.

Expert Reviews

Out of thirteen experts, six were male and seven were female. They have experience as ergonomists for an average of 11.76 years and have used RULA for an average of 3.8 years. The results show that experts rate the RULA Eye the highest. The average score is 4.23-4.85. The second highest is the checklist software. The average score is 3 – 3.77. The paper based RULA received the lowest scores. Its average score is 2.15-2.77. In the interviews, many experts suggested that the RULA eye has the advantage in computing, including fast calculations of table scores in real time, recording both the left and right parts of the body simultaneously, and recording over long durations. With regard to the usability of the tool, it is easy to setup, unobtrusive during observation, and provides ease in evaluation and data storing as a data logger. For the application, this tool can be used for many subjects and can be applied to other workstations.

Table 1. Expert evaluation of tools

Evaluation Criteria	Mean			F	Sig.
	Paper based RULA	ErgoIntelligence Check-list RULA software	RULA Eye Computer-aided posture analysis		
1. Ease for calculation	2.62	3.77	4.69	27.91	0.00**
2. Recording left and right parts of body simultaneously	2.62	3.54	4.46	22.73	0.00**
3. Recording in long duration	2.15	3	4.77	24.51	0.00**
4. Accuracy of data collection for novice	2.62	3.46	4.46	22.78	0.00**
5. Ease for setup	2.85	3.77	4.46	12.18	0.00**
6. Unobtrusive observation	2.92	3.38	4.23	7.27	0.002**
7. Ease for evaluation	2.77	3.77	4.62	25.47	0.00**
8. Record as a data log	2.46	3	4.77	24.77	0.00**
9. Apply for large group of subjects	2.46	3.46	4.85	36.96	0.00**
10. Apply for other postures	2.69	3.31	4.77	29.84	0.00**

DISCUSSION

The ranged camera is accurate when facing the joint angles perpendicular to the camera. It is important to note that this is not true for the trunk and neck parts. Body parts with long lengths, like upper arms and lower arms, are more reliable than body parts with short lengths or unclear joint angles like trunks and necks. The wrist is impossible to track. For this wrist problem, image-processing technology could be used to track the hand contours instead. An algorithm could also be developed that can estimate the parts of the body that may be blocked by other objects.

CONCLUSION AND FUTURE WORK

Experts reviewed the benefits of RULA eye over other RULA tools, since it functions as a data logger and provides automatic analysis. Most of the problems identified by the study are related to the low fidelity of the ranged camera, an issue that pertains to the hardware. Recently, Microsoft has developed a new ranged camera – Xbox one – and has released the beta version of SDK. The new Kinect has greater accuracy with three times the fidelity over its predecessor, and it can track without visible light by using active IR sensors. It can detect the position and orientation of small parts including thumbs. The new Kinect version promises the reliability of an enhanced ergonomics assessment tool.

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REFERENCES

- Chang, CY., Lange, B. Koenig, S., Requejo, P., Somboon, N., Sawchuk, AA., & Rizzo, A. (2012) Towards pervasive physical rehabilitation using Microsoft Kinect. In Pervasive Computing Technologies for Healthcare (PrevasiveHealth), 6th International Conference. 21-24 May 2012. San Diego, California, USA: IEEE; 2012: 159-162
- Cook, C. Burgess-Limerick, R. & Chang, S. (2000) The prevalence of neck and upper extremity musculoskeletal

- symptoms in computer mouse users, *Int. J. Ind. Ergon.* 26, 347-356.
- Haggag, H. Hossny, M. Nahavandi, S & Creighton, D. (2013) Real time ergonomic assessment for assembly operations using Kinect, *2013 UKSim 15th International Conference on Computer Modeling and Simulation*, April 10-12, 495-500.
- Hignett, S. & McAtamney, L. (2000) Rapid entire body assessment (REBA), *Appl. Ergon*, 31, 201–205.
- Horejsi, P., Gorner, T., Kurkin, O., Polasek, P., & Januska, M. (2013) Using Kinect Technology Equipment for Ergonomics, *MM Science Journal*, 390-391.
- Katz, J.N., Amick, B.C., Carroll, B.B. (2000) Prevalence of upper extremity musculoskeletal disorders in college students. *Am. J. Med.* 109, 586-588.
- Lueder, R. (1996) A Proposed RULA for Computer Users. In: *Proceedings of the Ergonomics Summer Workshop*, UC Berkeley Center for Occupational & Environmental Health Continuing Education Program, San Francisco.
- Luinge, H.J. & Veltink, P.H. (2005) Measuring orientation of human body segments using miniature gyroscopes and accelerometers. *Medical and Biological Engineering and Computing.* 43 (2) 273-282.
- McAtamney, L., & Nigel Corlett, E. (1993) RULA: a survey method for the investigation of work-related upper limb disorders. *Appl. Ergon.* 24 (2), 91e99.
- Mentiplay, BF., Clark, RA., Mullins, A., Bryant, AL., Bartold, S., & Paterson, K. (2013) Reliability and validity of the Microsoft Kinect for evaluating static foot posture. *J Foot Ankle Res.* Apr 8, 6(1): 14. doi:10.1186/1757-1146-6-14.
- National Statistical Office (2012) The Information and Communication Technology Survey in Establishment, Ministry of Information and Communication Technology. Retrieved from http://web.nso.go.th/en/stat_theme_ict.htm
- Nexgen Ergonomics (2014) ErgoIntelligence™ Upper Extremity Assessment (UEA) Retrieved from <http://www.nexgenergo.com/ergonomics/ergointel.html>
- Osmond Ergonomics (2014) RULA- Rapid Upper Limb Assessment. Retrieved from <http://www.rula.co.uk>
- Sonne, M., Villalta, DL., & Andrews, DM., (2012) Development and evaluation of an office ergonomic risk checklist: ROSA-Rapid office strain assessment, *Appl. Ergon*, 43, 2012.
- Tittiranonda, P., Rempel, D., Armstrong, T., & Burastero, S. (1999) Effect of four computer keyboards in computer users with upper extremity musculoskeletal disorders. *Am. J. Ind. Med.* 35, 647-661.