International Journal of Integrated Engineering: Special issue 2018: Mechanical Engineering, Vol. 10 No. 5 (2018) p. 164-169
© Penerbit UTHM
DOI: https://doi.org/10.30880/ijie.2018.10.05.024

Analysis of Musculoskeletal Disorder Due To Working Postures via Dual Camera Motion Capture System

Mohd Zamani bin Ngali*, Noratika Budi binti Jemain, Wee Chang An, Mohd Nasrull bin Abdol Rahman, Muhammad Zulhilmi Bin Kaharuddin, Siti Badriah Binti Khairu Razak

Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

Received 1 August 2018; Accepted 16 August 2018; Available online 30 October 2018

Abstract: Ergonomic are known as the study of work. It helps the worker to fit with the environment of the workplace for example the tools, equipment and the work station. Poor ergonomic practice can affect the performance of the worker and the quality of the product besides causing loss to the company. This study have three main purposes which is to establish the optimal set up of the dynamic RULA analysis in UTHM, to compare the performance of static RULA analysis with the current dynamic RULA analysis and to identify the effect of current working posture to the musculoskeletal disorder of the university staffs. The ergonomic tools that was used in this study are Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) and Rapid upper limb assessment (RULA). Besides that, motion captures system and Kinect camera were used for 3D dynamic RULA analysis. Meanwhile, 2D static analysis recorded the video of the subject motion simultaneously to quantitatively compare the result to 3D dynamic analysis. This research found that the 3D dynamic analysis is more accurate compare with the 2D static analysis. This can be proved by comparing the length of the joint point of 2D static analysis and 3D dynamic analysis with the actual length. 3D dynamic method provided 3 axes while the other method only provided 2 axes. 3D dynamic method in this paper was analyzed numerically by a software while 2D static method was analyzed manually by the user and prone to human error and thus not entirely accurate. The result for comparing the performance of the 2D static analysis and 3D dynamic analysis showed that the respondent 1 and 2 have high risk on getting neck pain based on the RULA score. CMDQ analysis showed that the body part of respondent 1 and 2 that are most probably affected by MSD was leg.

Keywords: Ergonomic, Kinect camera, working postures, RULA analysis, MSD problem, CMDQ, motion capture system (Mocap)

1. Introduction

Ergonomics is the process of designing or arranging workplaces, products and systems that will fit the human comfort requirement. Besides, ergonomics is applying to design anything that involving people including workspaces, sports and leisure. The relationships of the tools that support the activity and workplace with the user interact should be emphasize. The problem that may occurred during the activity process usually related with the surrounding workspaces and the user that have greater physical needs [1]. In the study by Deros et al. [2], only 18.8% of the workers realized the bad consequence of neglecting ergonomics. The tools should be able to fulfill both of the requirement, so that the worker can used it comfortably. As the results, it will reduce the hazard while working and able to handle the constraint very well [3].

Inappropriate ergonomics can lead to the work-related injuries and illnesses such as Musculoskeletal Disorders (MSDs), Cumulative Trauma Disorders (CTDs) and Repetitive Strain Injuries (RSIs). These diseases occurred due to bad postures while doing a work for example lifting a heavy object and doing a repetitive task. MSDs are the injuries or pain in the body's joint, ligaments, muscles, nerves, tendons and structures that support limbs, neck and back. The common causes of MSDs are making same repetitive motion strain, exposure to the force, vibration and awkward posture repeatedly. Moreover, work-related neck and upper limb musculoskeletal disorder are a significant problem in the European Union with respect to ill health and cost [4]. Horprasert and Haritaoglu [5] stated that the function of real-time 3D computer vision system is for detecting and tracking human movement. Moreover, the advantages of this research are they provided a virtual computer graphics character for those who control the movement. According to another research, they used marker-less human motion capture. According to Bregler et al. [6],

*Corresponding author: zamani@uthm.edu.my

they mentioned another method of motion capture system that is by using kinematic chain by twist and estimate the pose by local optimization. In this paper, Kinect sensors were used as the tools to markelessly capture body posture of a subject. The mentioned sensors have wide application in biomedical and sports fields. Nizam et al. used it for human fall detection systems [8] and Tomari et al. used it to obtain surrounding information for controlling a wheelchair [9].

2. Numerical Model

Since two Kinect sensors were used in capturing the subject of interest, the data (skeleton) obtained in both devices needs to be calibrated and merged into a single model. Such calculation employed the rigid transformation theory into this context [7].

A skeleton was divided into three potions: upper; middle; and lower section. A random joint from each section was selected. The three selected joints was then used to compute the rigid transformation as described in Eqn. 1.

$$B = \boldsymbol{R} * A + \boldsymbol{t} \quad (1)$$

Where $\boldsymbol{R}$, $\boldsymbol{t}$ are the transforms applied to dataset A to align it with dataset B, as best as possible. To solve the equation, it involved three steps: computation the centroids of both dataset; moving of both dataset to the origin and then evaluate the optimal rotation, (matrix $\boldsymbol{R}$) and; calculation of the translation, $\boldsymbol{t}$. Fig. 1 below described the process graphically.

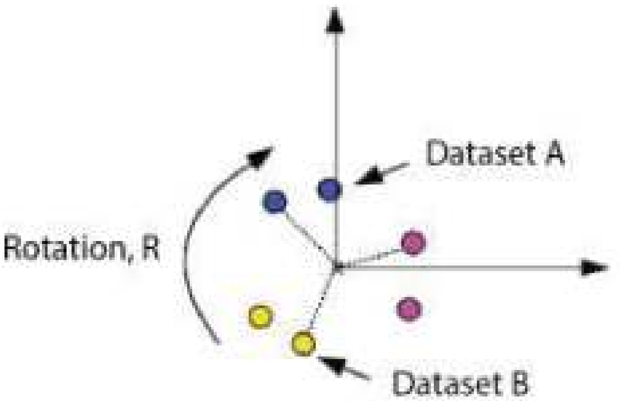


Fig. 1 - Moving data set A and B to origin and rotate the data [7].

3. Methodology

The flowchart of methodology process of this paper is shown in Fig. 2. First, a suitable case study was chosen and followed surveys. Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) is one of the ways to collect data by distributing questionnaire among the workers. The purposes of CMDQ was to identify daily ergonomics problem and to determine the general hazard on the chosen case study. Next, Rapid Upper Limb Assessment (RULA) was proceeded for the risk assessment. Here, both 2D and 3D analysis were done. This assessment used to investigate the postural body analysis. Moreover, a simple questionnaire was distributed to the workers which have no basic about the ergonomic to evaluate their understanding regarding the ergonomic. Finally the collected data were tabulated and analysis were done.

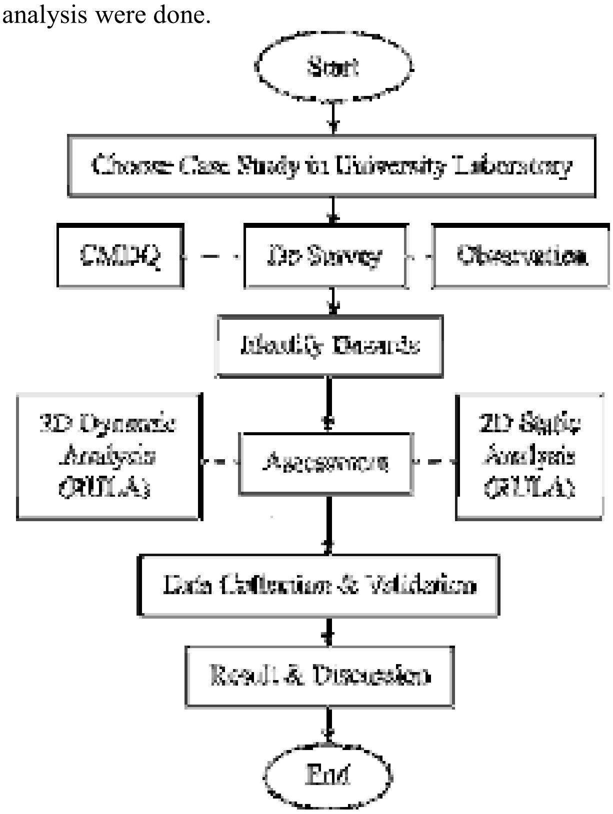


Fig. 2 – Flowchart to research.

4. Results and Discussion

This section discussed the result obtained from the experiment.

4.1 Data Validation for Respondent 1 and 2

The data validation of the respondent 1 was used to ensuring that the conducted experiment was correct and based on the actual length that are obtain from the 3D dynamic analysis as shown in Fig. 2. The length for both 2D static analysis and 3D dynamic analysis were acquired by manual calculation.

4.2 CMDQ

The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) analysis result obtained for both of the respondents is shown in Table 2 and graphically in Fig. 3 below.

4.3 Data Validation

The data validation was used to ensuring that the experiments conducted were correct and to compare which methods are more applicable. Moreover, the score that was obtained from 2D static analysis and 3D dynamic analysis will be compared based on angle for both methods. The angle of 3D dynamic analysis was acquired from the software itself, while the angle for the 2D static analysis was measured manually by the user as shown in Table 1.

Table 1 - Measured length by 2D and 3D analysis method for respondent 1 and 2.

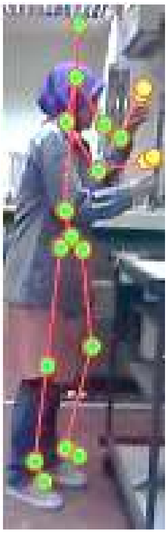
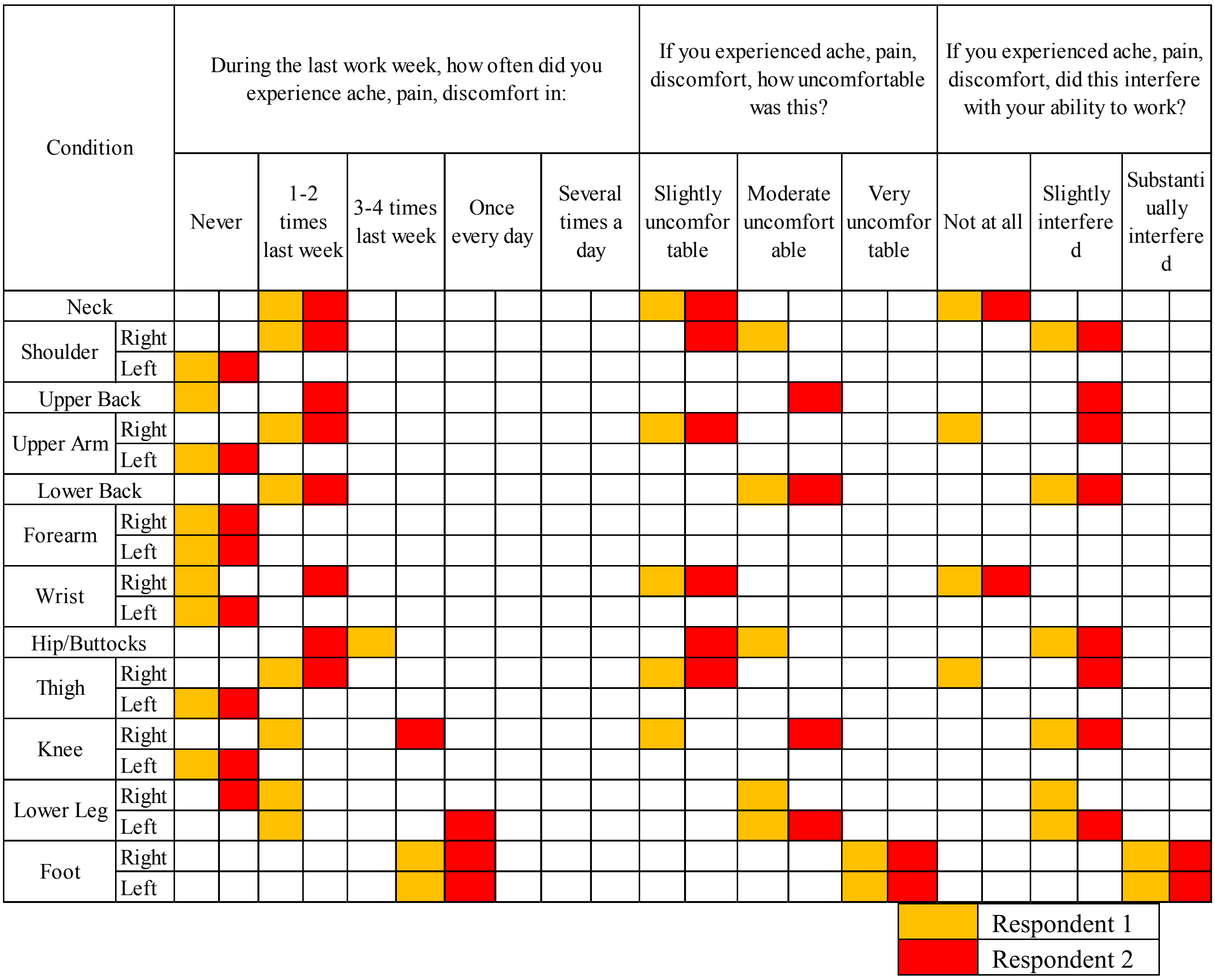
	Respondent 1				**Respondent 2**			
Posture 1	**2D Static**		**3D Dynamic**		**2D Static**		**3D Dynamic**	
Upper arm	**Actual Length : 2.9**				**Actual Length : 1.1**			
Length		3.4	2.6			1.6	1.2	
Score		2	1			1	1	
Lower arm		**Actual Length : 2.5**				**Actual Length : 0.9**		
Length		2.7	2.0			1.1	0.8	
Score		2	2			1	1	
Wrist		**Actual Length : 1.0**				**Actual Length : 0.3**		
Length		1.1	0.9			0.4	0.3	
Score		1	2			1	2	
Neck		**Actual Length : 2.4**				**Actual Length : 1.6**		
Length		2.8	1.7			1.9	1.5	
Score		1	2			3	2	
Trunk		**Actual Length : 4.6**				**Actual Length : 3.9**		
Length		4.9	4.4			4.3	4.1	
Score		2	3			1	2	

Table 2 - The result of CMDQ analysis for respondent 1 and respondent 2



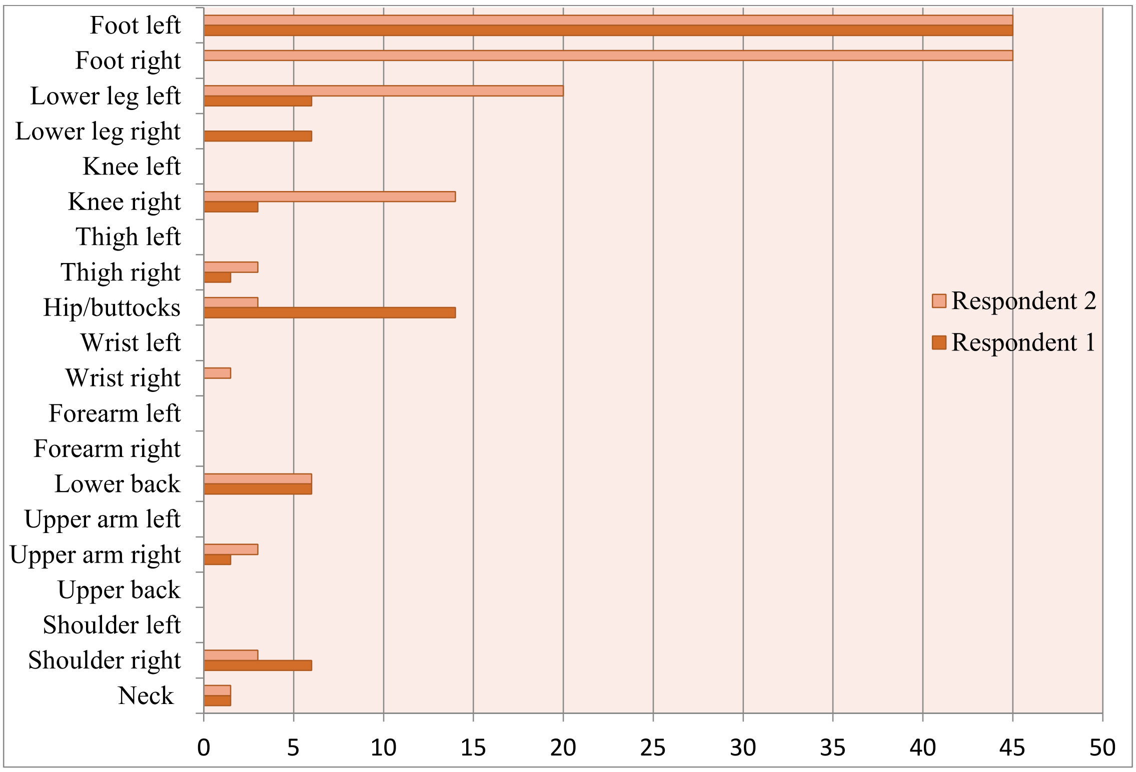


Fig. 3 - The result of CMDQ score for respondent 1 and respondent 2

International Journal of Integrated Engineering: Special issue 2018: Mechanical Engineering, Vol. 10 No. 5 (2018) p. 164-169
© Penerbit UTHM
DOI: https://doi.org/10.30880/ijie.xx.xx.xxxx.xx.xxxx

4.4 Discussion

The result analysis of the respondent 1 and 2 shows that neck obtained the highest score of 3D dynamic RULA analysis and this is based on the reference posture for both of the respondent. Therefore, the possibility of the respondent getting neck pain is higher compared to the other disease based on the 3D dynamic RULA analysis.

While, for 2D static RULA analysis shows that respondent 1 might probably have tendency to get Rotator cuff tendinitis and Tenosynovitis disease based on the musculoskeletal disorder (MSDs) chart [10] that relate with the hand, since the upper arm get the highest score for the respondent 1. The highest score of the respondent 2 is neck score. Thus, respondent 2 will expose to the neck pain.

From CMDQ analysis, both of the respondent state that the leg is the body part that are the most affected by the MSDs. The most possible injuries that respondents would suffered from are Tenosynovitis, carpal tunnel syndrome and back disability. These injuries could be detected by several symptoms which are pain, swelling, numbness in the upper legs and severe pain

4.5 Performance of 3D analysis and its potential

This section discussed the overall performance of 3D dynamic analysis using Kinect as sensors as well as its potential application in related fields. Overall overview by applying RULA dynamic analysis:

i. Real time result

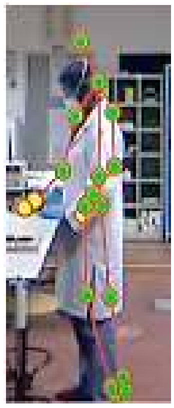
The RULA score of dynamic analysis was obtained at real-time and almost instantly. As shown in Table 3 below, the result of the data are obtained instantaneously. There is no need to analyse it manually in contrast to RULA static analysis that requires manual analyses. Besides, it saved substantial amount of time as compared to frame by frame analyses in RULA static analysis.

ii. Accurate result

The RULA dynamic method are using 3 axes for analysis which is x-axis, y-axis and z-axis. While, RULA static method uses only 2 axes; x-axis and y-axis. Thus, by comparing the axes, RULA dynamic method is more accurate than the latter. Moreover, since the result of RULA dynamic analysis was numerically obtained from programme and software, the result accuracy is thus undoubtedly have higher precision. In comparison, the result obtained from the RULA static analysis could be questionable since the analysis is obtained from manual calculations and exposed to human errors.

The angle of the camera also influenced the accuracy of the data obtained as shown in Fig. 6. For dynamic RULA, the set-up for the Kinect camera required some time to ensure that the whole body part are include in the analysis and to obtains the best angle of shooting that will affect the accuracy of the result. Even though static RULA method uses less time to set-up compared with the dynamic RULA method, it does not taking into consideration about the angle of the camera while recording the video, and as the consequence, the result are not precise.

Table 3 - Measured anlge by 2D and 3D analysis method for respondent 1 and 2.

Posture 1	2D Static	3D Dynamic
Upper arm	**Angle (°)**	
		
Angle	60	85
Score	1	1
Lower arm		
Angle	30	45
Score	1	1
Wrist		
Angle	8	15
Score	1	2
Neck		
Angle	21	15
Score	3	2
Trunk		
Angle	0	8
Score	1	2

iii. Potential application

The 3D dynamic method could be widely applied in any field such as alarm system, instructional system and monitoring system. These applications need real time result that will help warn the user if there is suspicious movement in monitoring sick people or around the private property.

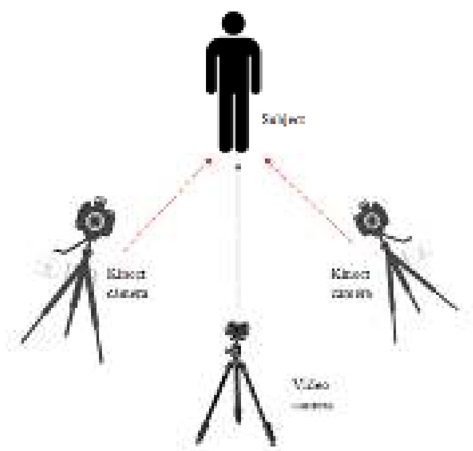


Fig. 6 - The schematic of the angle shooting for 3D dynamic analysis (Kinect camera) and 2D static analysis (video camera)

*Corresponding author: zamani@uthm.edu.my

5. Summary

This paper demonstrated that 3D dynamic analysis of RULA score is more accurate than conventional 2D static analysis. The fact that such method saved health or safety officer significant amount of time in obtaining RULA score makes it suitable for instant measuring and feedback of the score at the spot to the workers.

However, there are several limitations of the motion capture system such as the needs to consider of the space to set up the equipment and it take time to find the best angle of shooting. Besides, the result of respondent 1 and 2 which comparing the length of the joint point of 2D static analysis and 3D dynamic analysis showed that the value of 3D dynamic analysis for both respondents was close to the actual length. This indicates that the 3D dynamic analysis is much accurate compared with the 2D static analysis. This is because 3D dynamic method provided 3 axes while the other method only provided 2 axes. Moreover, 3D dynamic method are analyzed by a software while 2D static method are analyzed manually by the user that prone to errors. From the analysis of 2D static method and 3D dynamic method, it showed that there are no certainty that the result of 3D dynamic analysis will always obtain a bad posture of the respondent, while 2D static analysis only obtain a good posture. This could be vice versa since the results are based on the camera angle of shooting and the angle obtains from the analysis.

6. Acknowledgement

This research is supported by the Fundamental Research Grant Scheme (FRGS), Grant No: FRGS/2/2015 Vot 1543 by Ministry of Education, Malaysia.

References

[1] I. Gonzalez and P. Morer, "*Ergonomics for the inclusion of older workers in the knowledge workforce and a guidance tool for designers,*" Appl. Ergon., vol. 53, (2016), pp. 131–142.

[2] B. M. Deros, D. D. I. Daruis, and I. M. Basir, "*A Study on Ergonomic Awareness among Workers Performing Manual Material Handling Activities,*" Procedia - Soc. Behav. Sci., vol. 195, (2015), pp. 1666–1673.

[3] F. Gauthier and D. Lagacé, "*Critical Success Factors in the Development and Implementation of Special Purpose Industrial Tools: An Ergonomic Perspective,*" Procedia Manuf., vol. 3, no. Ahfe, (2015), pp. 5639–5646.

[4] P. W. Buckle and J. Jason Devereux, "*The nature of work-related neck and upper limb musculoskeletal disorders,*" Appl. Ergon., vol. 33, no. 3, (2002), pp. 207–217.

[5] Horprasert, T., Haritaoglu, I., Wren, C., Harwood, D., Davis, L., & Pentland, A., "*Real-time 3d motion capture,*" Second workshop on perceptual interfaces (Vol. 2), (1998, November).

[6] C. Bregler, J. Malik, and K. Pullen, "*Twist based acquisition and tracking of animal and human kinematics,*" Int. J. Comput. Vis., vol. 56, no. 3, (2004), pp. 179–194.

[7] An, W. C., Ngali, M. Z., Kaharuddin, Z., & Razak, S. B. K., "*Performance of Dual Depth Camera Motion Capture System for Athletes' Biomechanics Analysis,*". *MATEC Web of Conferences*, vol. 135, (2017), p. 00059, EDP Sciences.

[8] Nizam, Y., Jamil, M. M. A., Mohd, M. N. H., Youseffi, M., & Denyer, M. C. T., "*A Novel Algorithm for Human Fall Detection using Height, Velocity and Position of the Subject from Depth Maps,*" International Journal of Integrated Engineering, *10*(3), (2018), pp. 32-41.

[9] Tomari, M. R., "*A framework for controlling wheelchair motion by using gaze information,*" International journal of integrated engineering, *5*(3), (2014), pp. 40-45.

[10] O. S. and H. Administration, "*Ergonomics : The Study of Work,*" U.S. Dep. Labor, vol. 2000, (2000), pp. 1–14.