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DEVELOPMENT OF A MOTION CAPTURE SYSTEM USING KINECT

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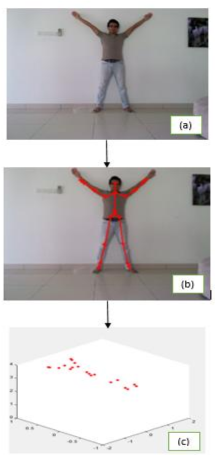
Graphical abstract



Abstract

Microsoft Kinect has been identified as a potential alternative tool in the field of motion capture due to its simplicity and low cost. To date, the application and potential of Microsoft Kinect has been vigorously explored especially for entertainment and gaming purposes. However, its motion capture capability in terms of repeatability and reproducibility is still not well addressed. Therefore, this study aims to explore and develop a motion capture system using Microsoft Kinect; focusing on developing the interface, motion capture protocol as well as measurement analysis. The work is divided into several stages which include installation (Microsoft Kinect and MATLAB); parameters and experimental setup, interface development; protocols development; motion capture; data tracking and measurement analysis. The results are promising, where the variances are found to be less than 1% for both repeatability and reproducibility analysis. This proves that the current study is significant and the gained knowledge could contribute to enhancing the capability of Microsoft Kinect as a motion capture system.

Keywords: Microsoft kinect, motion capture system, measurement analysis, repeatability, reproducibility.

1.0 INTRODUCTION

Recent development in entertainment and gaming systems has brought natural and intuitive human computer interfaces to our lives [1][2]. In an effort to evaluate and simulate human movement in a natural setting, motion capture systems have been developed. Contribution towards the 3D-CG animation, film industry, and video games makes the practice of motion capture technology has grown exponentially in both its use as a research tool and for clinical assessments [3][4][5]. The production of 3D animated content requires a large database of body motion because motion capture provides accurate and natural motion data which makes the reuse of motion data becoming gradually significant [5]. The examples of motion capture system are Kinect, Vicon3D, and etc. The conventional motion capture systems, for example Vicon3D, are marker based which often require precise, tedious, and time consuming marker preparation. This expensive equipment usually dependence on technical expertise which make the usage of motion capture systems become limited especially in clinical settings [6]. Whereas the Kinect, on the other hand is a promptly developing with reasonable price as well as portable and marker-less. It can interpret and track 3D body gestures in real time [6]. Consequently, Kinect is a cost-effective alternative to motion capture systems. Microsoft Kinect is a low cost motion sensing technologies which consist of a video camera, depth camera, and an IR camera [7], and thus providing an attractive alternative in the motion sensors system. To date, the application and potential of Microsoft Kinect has been vigorously explored especially for entertainment and gaming purposes. However, its motion capture capability in terms of repeatability and reproducibility is still not well addressed [8]. Therefore, this study aims to explore and develop a motion capture sstem using

Microsoft Kinect; focusing on developing the interface, motion capture protocol as well as measurement analysis. The work is divided into several stages which include installation (Microsoft Kinect and MATLAB); parameters and experimental setup, interface development; protocols development; motion capture; data tracking and measurement analysis.

2.0 METHODOLOGY

The flow chart in Figure 1 illustrates the overall flow of the study.

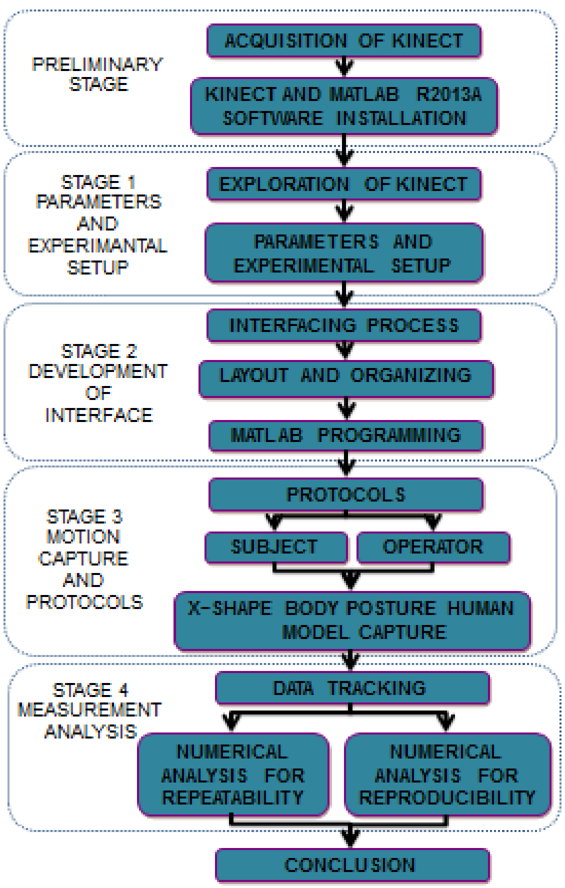


Figure 1 Process flow

In general, this research comprises of experimental and numerical approaches that have been conducted in several stages:

Preliminary Stage: Software Installation
Stage 1: Parameters and Experimental setup
Stage 2: Development of Interface
Stage 3: Motion Capture and Protocols
Stage 4: Measurement Analysis

Stage 1: Parameters and Experimental Setup

The experimental set up consists of a Kinect sensor connected to the USB port of a laptop running the Windows 8 operating system. The system is used to capture the motion both in static and dynamic movement. The captured motion by referring to Microsoft, the body posture joint indices which consists of 20 coordinate as in Figure 2 is then tracked by an open source software MATLAB R2013a. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. MATLAB is capable to analyse data, develop algorithms, and create models and applications. Furthermore, MATLAB is used for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology.

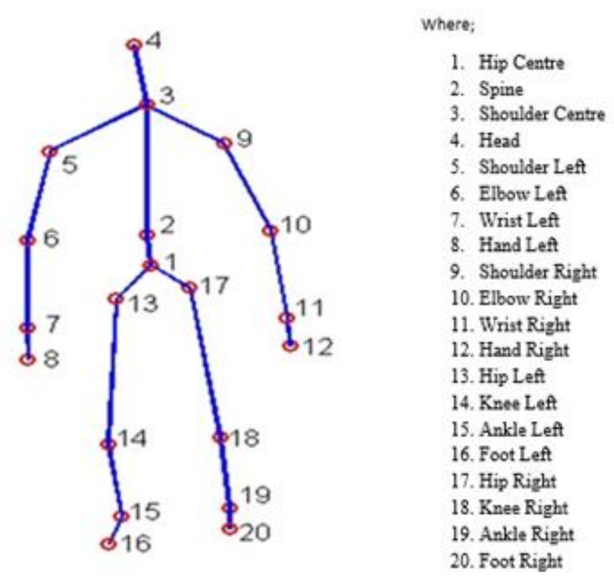


Figure 2 Body Posture Indices

Stage 2: Development of Interface

After both Kinect and MATLAB R2013a installed successfully, coding to run the system is set into MATLAB R2013a for tracking the motion, which then extracted the data simultaneously. The development of interface is divided into three main phases:

Phase 1: Interfacing
Phase 2: Layout and Organising
Phase 3: MATLAB Programming

Phase 1: Interfacing

The interfacing process between Microsoft Kinect and MATLAB R2013a is crucial in order to generate reliable data. Both of the softwares must be compatible as the data from the Microsoft Kinect are synchronised with the data extracted into MATLAB. The interfacing process includes generating coding to run the overall flow from capturing subject to the data tabulation. Thus, generating the coding to run the MATLAB R2013a is essential otherwise the system is unable to run the overall flow of tracking and capturing the motion of human from Kinect. In order to identify the data of 20 coordinates in x, y and z axes, another subroutine is generated to identify the coordinate point of the human model motion as the raw data scatters.

Phase 2: Layout and Organising

Furthermore, the needs to run the system in orderly manner and to avoid confusion leads to the process of layout and organising of the entire program.

Phase 3: MATLAB Programming

A finalise coding from initiating the system to generating and extracting the data as well as the entire orderly program is illustrated in Figure 3.

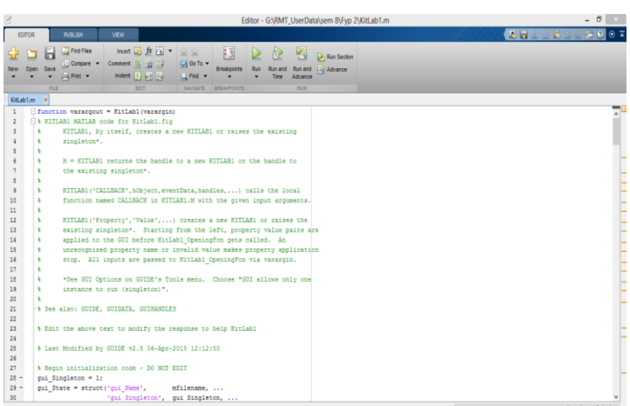


Figure 3 MATLAB code for the entire system

Stage 3: Motion Capture and Protocols

Twelve young adults; two as the human subjects and ten as the operators (Target: age 25 ± 7 years; height 160 ± 20 cm; students) were recruited from the Faculty of Mechanical Engineering, UiTM Shah Alam to participate in this study. The subjects must be healthy and fit as well as free from any physical conditions. Firstly, protocol is developed as part of the procedure to systematically capture the motion of human subjects. The two protocols are the subject's protocol and operator's protocol. In the subject's protocol, the subject must be standing within the range of 2m from the Kinect eye. The Kinect eyes detect the skeleton of the subject and thus, the subject must be in the field of view (marked with an X–shape body posture). Other than that, clothes play an important role for the subject to comply. Only tight clothing is allowed to avoid confusion in the Kinect eye. Next, the crucial part is the operator's protocol. The operator must be able to conduct and run the software step by step accordingly. After the software (both Kinect and MATLAB R2013a) is opened and coding is run, the operator must record the relevant information provided i.e. name, age, height, weight time of capture and file name. As in this experiment the time of capture is set as constant which is 7 seconds. Specifically, the file name is important in order for the data to store accordingly. Other than that, the preview is available to check on the Kinect eye projection. Along the way, the operator must follow the commands of the program. The flow chart in Figure 4 and Figure 5 illustrate the protocol for the subjects and operators respectively.

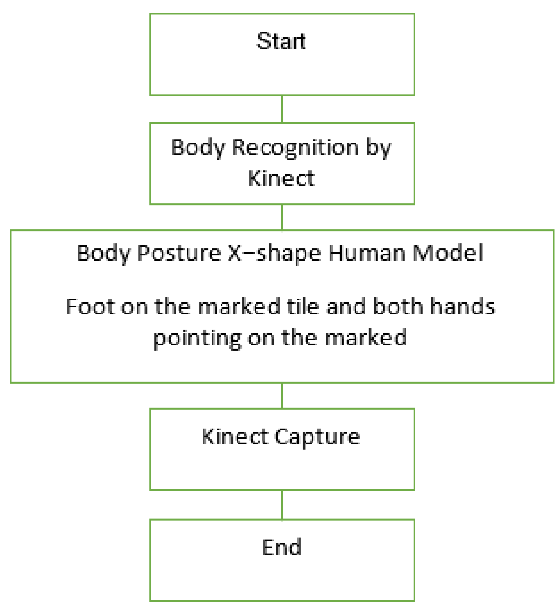


Figure 4 Flowchart of subject's protocol

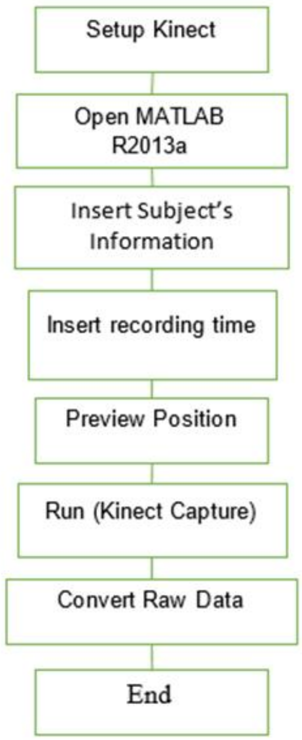


Figure 5 Flowchart of operator's protocol

Stage 4: Measurement Analysis

To measure the repeatability and reproducibility of the system, the protocol is repeated and the same motion is captured ten times. In this study, the motion of the X-body posture is recorded and repeated ten times. Then, the data is tabulated and

- Euclidean distance is measured using Equation 1,
- average mean is calculated using Equation 2,
- standard deviation is calculated using Equation 3; and
- variance is calculated using Equation 4.

The criterion of repeatability and reproducibility is the variance must be less than 5%.

$$Euclidean\ distance = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \quad (1)$$

$$Average\ mean\ (\bar{x}) = \frac{\sum x}{n} \quad (2)$$

$$Standard\ deviation\ (SD) = \sqrt{\frac{\sum(x-\bar{x})^2}{n}} \quad (3)$$

$$Variance\ (SD^2) = \frac{\sum(x-\bar{x})^2}{n} \quad (4)$$

3.0 RESULTS AND DISCUSSION

Figure 6 illustrates a sample visualisation of the images seen by the observer with naked eyes, the tracked 20 coordinate skeleton of human model by the Microsoft Kinect system and MATLAB R2013a interface of raw data. Figure 7 illustrates the results of newly developed interface which is important in order to run the entire system.

Firstly, the coordinates that is taken into consideration in this study is coordinate of point 8; hand left, coordinate of point 20; foot right, coordinate of point 12; hand right and coordinate of point 16; foot left. The measurement analysis results for repeatability are presented in Table 2 and 3 for coordination of coordinates 8 and 20 and coordination of coordinates 12 and 16 respectively. From the Euclidean distance calculation which leads to the variance calculation has shown that measurement analysis for repeatability is less than 1%. Thus, it satisfies the criterion of the repeatability measurement which range must be than 5%. Figure 8 shows the tabulation data of X–shape body posture of human model analysis from the ten captures. From the ten captures, the data shown to be in the range value for each coordinates.

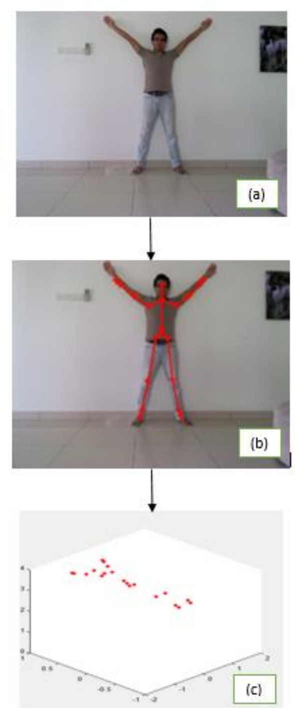
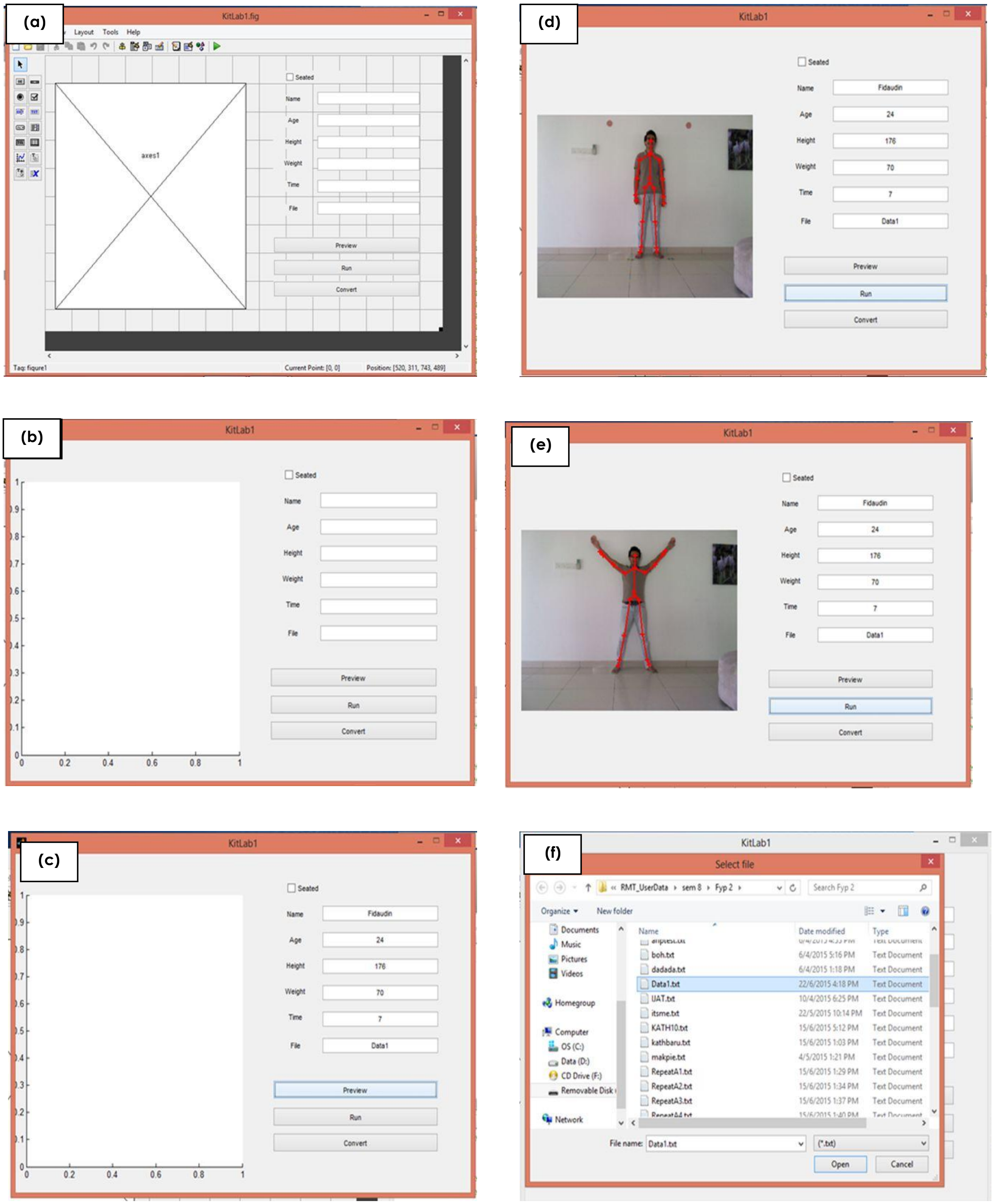


Figure 6 Output View: (a) The actual view without any device (Naked eyes); (b) View tracked by Microsoft Kinect system; (c) Data stored and visualisation using MATLAB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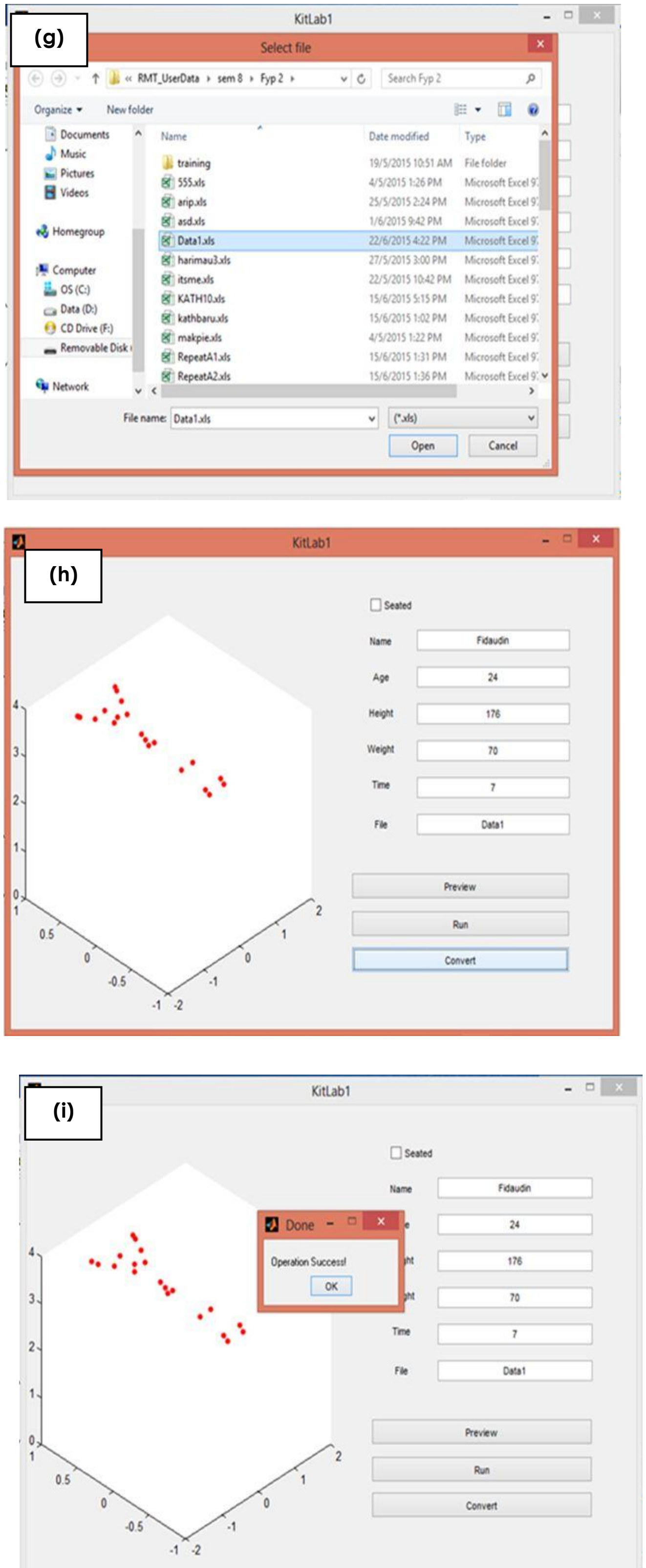

Figure 7 Newly developed interface

The description for the newly developed interface is illustrated in Table 1.

Table 1 Description for the newly developed interface

FIGURE 7	DESCRIPTION
(a)	Import the coding and run the system.
(b)	Fills in the information details i.e. name, age, height, weight, time for the data to be capture and file name to store the data.
(c)	Preview the field of view of Kinect eyes.
(d)	Run the program when the subject is in the field of view and the skeleton of 20 coordinates is detected.
(e)	The system is capturing the data at the given time.
(f)	The captured data file is access to convert it into readable data
(g)	Convert the data file in the form of excel.
(h)	As the conversion takes place the movements of the subject from initial to final time shown.
(i)	Once the conversion of data is done the entire operation is success.

Table 2 Coordinates of point 8 and point 20 for 10 trials

No of trial	Coordinate of point 8 (Left hand)			Coordinate of point 20 (Right foot)			Euclidean Distance
	X	**Y**	**Z**	**X**	**Y**	**Z**	
1	0.38087	0.74134	2.25740	0.44548	0.89165	2.46400	0.26354
2	0.38065	0.72420	2.25920	0.43527	0.88061	2.47530	0.27230
3	0.38570	0.72731	2.24210	0.39889	0.83613	2.45920	0.24320
4	0.35844	0.71964	2.25130	0.48286	0.86709	2.46340	0.28672
5	0.38009	0.72489	2.24390	0.48017	0.84904	2.46490	0.26811
6	0.26056	0.76076	2.25240	0.48980	0.88313	2.46100	0.33323
7	0.38272	0.72433	2.25180	0.43989	0.87372	2.46350	0.26534
8	0.37152	0.73631	2.24640	0.56944	0.89667	2.43360	0.31612
9	0.36742	0.72771	2.21080	0.51861	0.90236	2.46170	0.34105
10	0.37726	0.73343	2.24480	0.54391	0.91094	2.45740	0.32323

Average mean	Variance
0.537122	6.3040E-4(0.063%)

Table 3 Coordinates of point 12 and point 16 for 10 trials

No of trial	Coordinate of point 12 (Right hand)			Coordinate of point 16 (Left foot)			Euclidean Distance
	X	Y	Z	X	Y	Z	
1	0.38492	0.76153	2.29050	0.57132	0.88152	2.44250	0.26879
2	0.37336	0.72674	2.26140	0.57083	0.89330	2.44730	0.31827
3	0.37315	0.72781	2.26260	0.59073	0.92382	2.44560	0.34533
4	0.35408	0.72720	2.25990	0.62540	0.91072	2.44740	0.37743
5	0.39837	0.76271	2.32100	0.59565	0.90706	2.44870	0.27580
6	0.39769	0.76627	2.30720	0.59780	0.92104	2.44420	0.28770
7	0.36821	0.72374	2.27060	0.61954	0.92847	2.45700	0.37393
8	0.36940	0.72427	2.24040	0.58944	0.90885	2.45640	0.35937
9	0.36606	0.71979	2.27300	0.59405	0.90764	2.45060	0.34469
10	0.37035	0.72498	2.26110	0.61530	0.89826	2.45250	0.32964

Average mean	Variance
0.328095	1.40723E-3 (0.14%)

Table 4 Tabulation of reproducibility result for coordinates 8 and 20

No of trial	Coordinate of point 8 (Left hand)			Coordinate of point 20 (Right foot)			Euclidean Distance
	X	Y	Z	X	Y	Z	
1	0.59288	0.82507	2.48450	0.26453	0.75611	2.25740	0.40514
2	0.58916	0.85778	2.47380	0.27688	0.76050	2.26590	0.38756
3	0.62521	0.84958	2.47050	0.26357	0.75186	2.26490	0.42732
4	0.62456	0.83429	2.47470	0.26068	0.74973	2.28180	0.42044
5	0.56140	0.80387	2.45590	0.27334	0.76025	2.25570	0.35350
6	0.56093	0.86071	2.47000	0.26056	0.76076	2.25240	0.38414
7	0.60673	0.82590	2.47390	0.26849	0.75306	2.23000	0.42332
8	0.61581	0.84650	2.47940	0.27973	0.77362	2.27880	0.39812
9	0.59377	0.85323	2.47820	0.27476	0.76563	2.19280	0.43688
10	0.60874	0.88959	2.48270	0.26471	0.76183	2.23250	0.44416

Average mean	Variance
0.408046	1.2E-5(0.0012%)

Table 5 Tabulation of reproducibility result for coordinates 12 and 16

No of trial	Coordinate of point 12 (Right hand)			Coordinate of point 16 (Left foot)			Euclidean Distance
	X	Y	Z	X	Y	Z	
1	0.38087	0.74134	2.25740	0.44548	0.89165	2.46400	0.26354
2	0.38065	0.72420	2.25920	0.43527	0.88061	2.47530	0.27230
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10	0.37726	0.73343	2.24480	0.54391	0.91094	2.45740	0.32323

Average mean	Variance
0.301284	1.156E-3 (0.1156%)

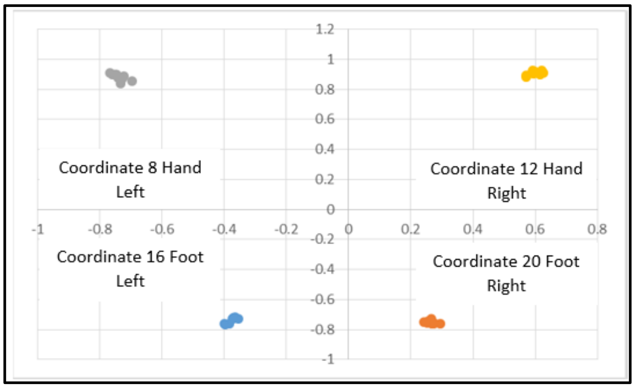

Figure 8 Tabulation of data for ten captures by a single operator (analysis of repeatability)

The measurement analysis results for reproducibility are presented in Table 4 and 5 for coordination of coordinates 8 and 20 and coordination of coordinates 12 and 16 respectively. From the Euclidean distance calculation which leads to the variance calculation has shown that measurement analysis for reproducibility is less than 1%. Figure 9 shows the tabulation data of X–shape body posture of human model analysis from the ten captures.

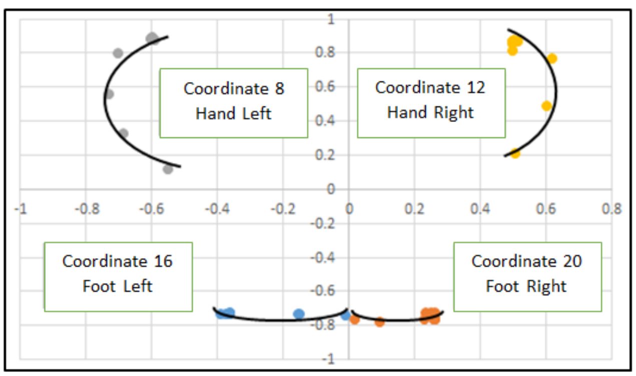

Figure 9 Tabulation of data for ten captures by a different operator (analysis of reproducibility)

The motion tracking of the four coordinate which are coordinate 8 hand (left), coordinate 12 hand (right), coordinate 16 foot (left) and coordinate 20 foot (right) are illustrated in Figure 10. The displacement of points in the x- and y-axes against time is depicted in Figure 11 and Figure 12.

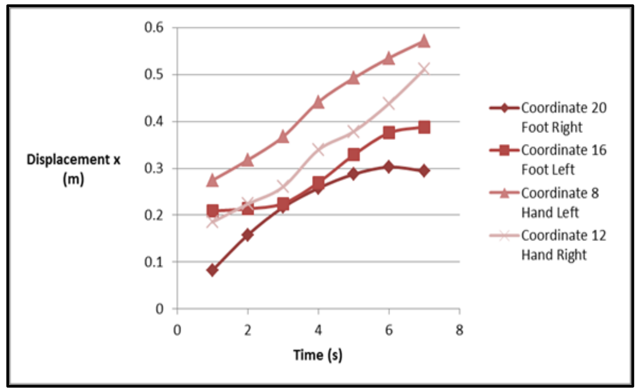

Figure 10 Motion tracking outputs

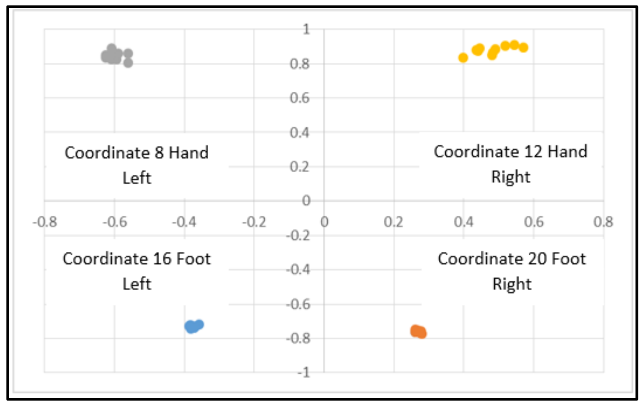

Figure 11 Displacements in x-axis versus time

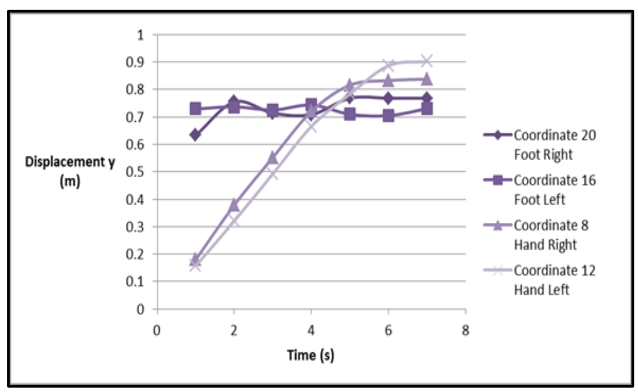

Figure 12 Displacements in y-axis versus time

The main challenges in the study include interfacing of Microsoft Kinect and MATLAB R2013a, developing protocol for subjects and operators, synchronising time of capture and storing data. Moreover, even though the experiments are performed in static condition; during the motion capture, any small movement is also detected and thus could lead to inaccurate tracking. In contrary, it is good to state that the time of capture is controlled and sufficient for an accurate capture of the X–shape body posture. In addition, the system is found to measure accurately and generated reliable data (repeatable and reproducible). The interface is found to be user friendly and displaying important information. The protocol is found to be useful for the measurement analysis. Thus, this achievement has shown that the current study is significant and has contributed to enhance knowledge about motion capture system using Kinect.

4.0 CONCLUSION

This study aims to develop interface and protocol for the Microsoft Kinect system. The system's repeatability and reproducibility has been evaluated prior to analysing the X-shape posture movement and the results prove that this aim has been achieved successfully. The measuring system has demonstrated an error of less than 5% variance; thus highlighting the potential of the Microsoft Kinect System to serve as an alternative low cost motion capture and analysis with reasonable accuracy. Nevertheless, future investigation should be carried out more comprehensively to enhance the capability of the system. Therefore, it could be concluded that the current study is important and has contributed to enhancing knowledge about Microsoft Kinect system as a low cost and simple measurement tool.

Acknowledgement

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