Gait Analysis using Kinect ™ as a Home Monitoring Instrument in Case of Spine Joint Movement

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***Abstract*—This study investigates the application of Kinect™ as a low-cost gait analysis instrument. Kinect™ is a virtual reality technology that is commercially available and has been used in gait studies recently. Kinect™ is much cheaper than the commonly used high-fidelity optical system. Here, we report a method to record human male subjects aged 25–26 years using a specific setup of gait aisle. Results show a data set comprising 25 data points representing the 25 human joints. This study focuses on the analysis of spine base movement for two subjects. The study produces a gait pattern in a repetitive cyclical data set. Statistical analysis of the pattern shows that the method can identify the walking signature for each subject. This study promotes the application of this method in identifying pathological issues, such as spinal disease, during medical rehabilitation in a practical and economical manner.**

Keywords*— *Gait Analysis, Kinect™, Human Joints, Walking Signature, Spine Base, Medical Rehabilitation

I. Introduction

Gait analysis is a study on human locomotion, particularly on how they walk. Walking is a rhythmical series of body parts that results in motion[1]. This human activity is a complex and important process. The gait pattern can be used to diagnose several abnormalities of the human locomotion system, such as stroke[2], Parkinson's disease, or neuromuscular disease[3]. Human gait is an important indicator of health[4], [5] that is utilized in many applications, such as fall detection[6] and risk prediction[7].

Analysis of clinical gait systems will be an interesting application in the future because of its accuracy, non-invasiveness, ease of use, and cost effectiveness in identifying a pre-operation patient and monitoring post-operation conditions thoroughly[8], [9], [10]. Recent studies have shown that Microsoft Kinect, which was initially developed as a video game tool to trace player motion, can be used to measure spatiotemporal gait variables and gait kinematics[11], [12]. This application covers an early diagnosis and an assessment of medical rehabilitation effectivity measurement at home[13], [14] and even optimizes a proper medication[15].

Kinect is cheaper than traditional gait analysis systems; thus, it can be used as an alternative tool to analyze motion at a cheaper price[16]. Nevertheless, the validity of this motion measurement tools needs to be validated before it can be applied in data collection. Recently, upper-body and lower-body joints have been investigated by Fernandez-Baena et al.[17], Nixon et al.[18], and Mobini et al.[19]. Huber[20] has also confirmed the reliability of Kinect to measure the shoulder joint. Additionally, Paolini et al.[21] introduced a method for tracking human movement in a treadmill. Their results suggest that Kinect has a tolerance result and great potential compared with the conventional gait setup.

This study aims to optimize a setup of gait mechanism that introduces gait aisle altogether with Kinect device arrangement. The system shall identify the walking pattern of human subjects with different gestures. Two similar male subjects are introduced in this experiment to emulate pre- and post-operation postures. Here, the specific target joint to be studied is the spinal base movement.

II. Methods

A. Kinect Setup

Kinect is used as a sensor to detect and take human walking images. Kinect then produces images of human bones that simulate bone movements in real time. The Kinect arrangement accustoms with an area to capture the full-body gesture.

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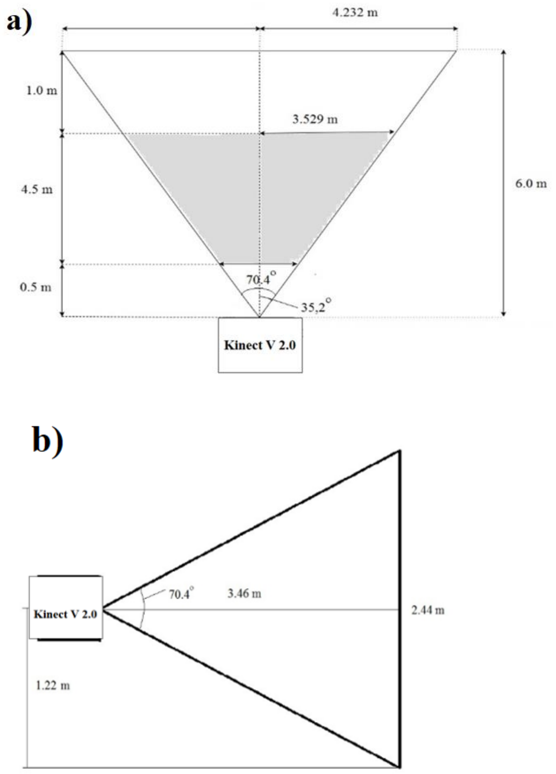

Fig. 1. Gait aisle and Kinect arrangement a) top view: the grey area is where the subject moves during data acquisition and b) side view of Kinect

Figure 1 is the placement of the Kinect device together with the aisle where the subject moves. The field of view (FoV) of the horizontal camera is 70.4°, whereas that of the vertical camera is ± 30°. The maximal distance of Kinect is 6 m, whereas the minimum distance is 0.5 m. Kinect cannot capture human images beyond this limitation distance. The maximum height of Indonesian people is assumed to be 2.0 m. After simple goniometric calculation, Kinect is placed around 1.2 m high. Thus, the effective distance of Kinect to people is ± 3.5 m with the effective path length of 4.8 m.

B. Data Acquisition

Kinect v 2.0, which integrates the camera and the sensor, is used to acquire image data. Kinect is connected to a PC using the Kinect adapter for Windows. The PC used is the ASUS S550C B-C J094H series laptop with 12 GB memory and Windows 10 OS.

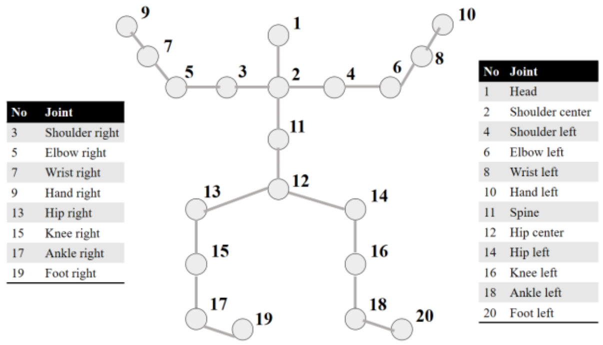

Fig. 2. Kinect V2.0 Maps of Joint in 1D that form human body into a matchstick figure

Image data are populated using the Visual Studio ™ 2015 program. The data obtained are Cartesian coordinates for all existing joints (Figure 2). Data retrieval standards include the following:

- The starting point of the moving subject, where the subject stands behind the sign before the data collection begins and the operator gives a signal to the subject
- Movement time
- Subject point completed

During an acquisition of one subject (person), a five-time-repetition is conducted. Here, two subjects are introduced to emulate different patient conditions, namely, pre-operation and post-operation. Both subjects are male aged 25–26 years. Subject 1 has a height of 164 and weight of 60 kg, whereas subject 2 has height of 167 cm and weight of 64 kg.

C. Data Processing

The data from the visual studio are extracted into Joints_Locs.txt using an m.file that is executed in a visual program. The txt file is then transferred to a Microsoft Excel spreadsheet and analyzed. The file is written in the form of 25 rows and 3 columns where 25 lines are the amount of data captured in 1 frame (1 frame = 1 portrait image). The three columns serve the Cartesian coordinate (x,y,z) of the subject.

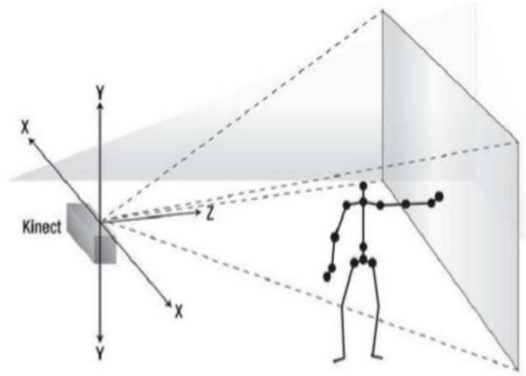

Fig. 3. Space coordinate for Kinect v2.0

III. Results and Discussion

A. *Gait Pattern Analysis*

Here, we only aim to process the spine base coordinate to be processed. Figure 4 is the result of data acquisition and processed in Microsoft visual studio. The data are then plotted in Figure 1 for the x-, y-, and z-coordinates after being exported to an Excel datasheet. Figure 4 shows the movement in the x-, y-, and z-directions in frame to frame. The data acquisition is set to 30 frames per second (fps), with 100–180 frames for each subject during the walking experiment. Then, the recorded time is calculated to be 3.3 s to 4 s. The subject walking velocity along the path length of 4.8 m is 1.48–1.06 m/s.

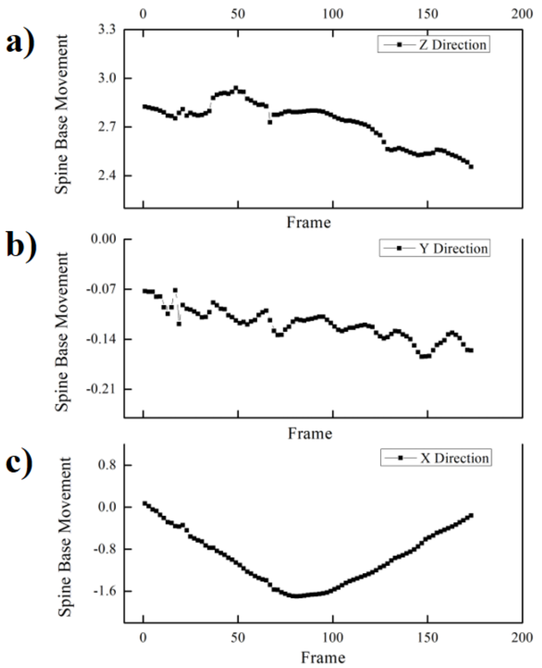

Fig. 4. Movement of a subject indicated by its spine base coordinate: a) z-direction; b) y-direction, and c) x-direction

During the experiment, the subject moves from left to right of the Kinect camera in the x-direction (Figure 3). The x coordinate gives the transversal movement of joint, which is taken only for the spine base joint in this case (Figure 4a). The y-coordinate indicates the upward and downward body movement during walk (Figure 4b). The coordinate in the z-direction shows the left/right movement of the subject or in lateral flexion with the Kinect camera (Figure 4c). As shown in Figure 4, the coordinate systems that give important information are the y- and z-coordinates. In these two coordinates, the spine has a small movement rather than in the x-direction with respect to its distance. Therefore, the gait pattern is more evident in the y- and z-coordinate system during our experiment.

Figure 5a shows the spine base movement along the walking path of subject no.1. An obvious repetitive pattern occurs in those around 100 frames. Estimations show that a cyclic movement occurs every 25 s. This cyclic movement represents the gait pattern

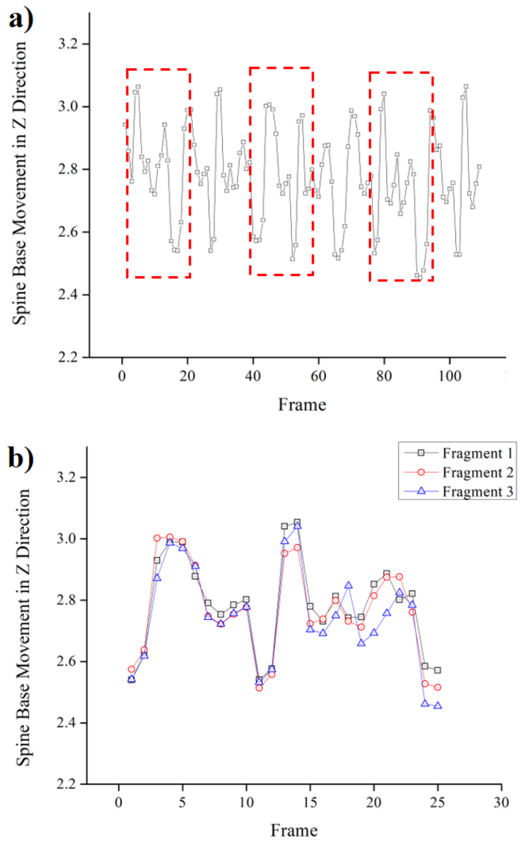

Fig. 5. Path of spine base in its z-direction from a subject during the walk: a) repetitive pattern is indicated and then fragmented into three parts; b) superposition of three fragments to be analyzed for similarity

of subject no.1. According to gait theory, this cycle shall consist of stance and swing phases. Moreover, we randomly took three cycles that fragmented from Figure 5a. Figure 5b shows the superposition of three paths of previous three fragments. Figuratively, those three fragments are assumed to have a similar pattern. The relative deviation is less than 3%, which makes those three fragments similar to each other. Moreover, ANOVA results show that their differences are not significant ($p=0.68$).

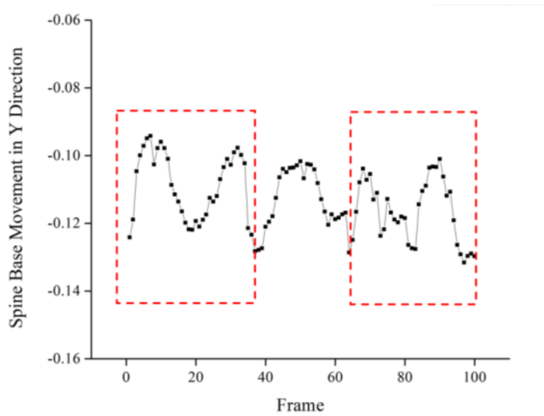

Fig. 6. Gait pattern of spine base in the y-direction and two fragments from the

Figure 6 shows a different gait pattern as shown by the spine joint previously described. The pattern and length of the cycle are different. Peak analysis shows that one cycle consists of around 40 frames. It has a longer cycle compared with that in the z-direction, which only has 25 frames to reach a cycle. Analogously, statistical analysis shows that the two frames have no significant difference ($p = 0.14$).

B. *Gait Pattern as Individual Walking Signature*

This study aims to distinguish the walking signature of patients. The device enables us to monitor the gait pattern of patients under pre-operation and post-operation conditions. Here, we introduce two subjects with individual walking signatures instead of pre- and post-operations. The spine base is already analyzed in the y- and z-directions. It creates a walking signature that forms 25 and 40 cyclical frames for the z- and y-coordinates, respectively.

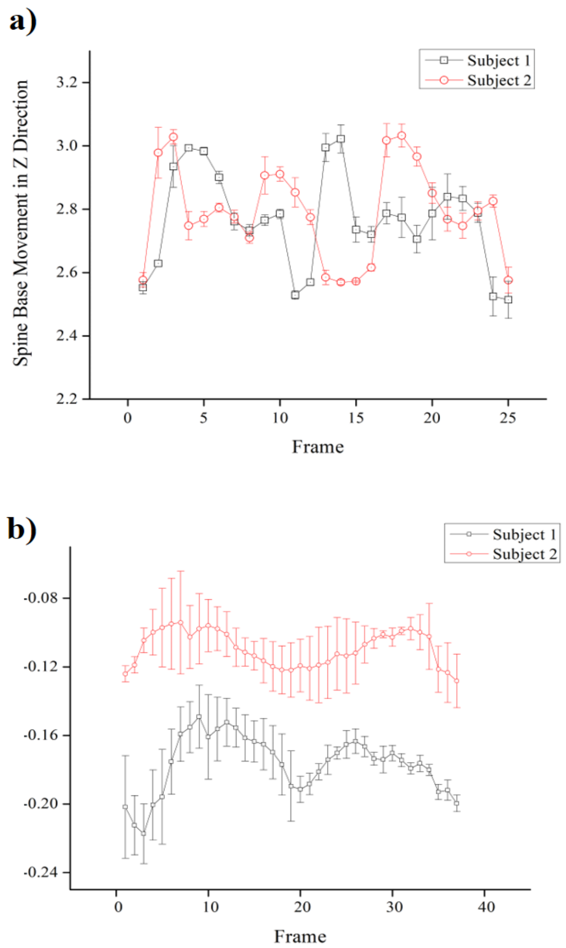

Fig. 7. a) Comparison of dataset for subjects 1 and 2 at the a) z-direction and b) y-direction

Figure 7a shows the z-direction of subject 1 and subject 2 that walked individually during our experiment. The gait pattern of subject a is significantly different from that of subject 2. Similarly, Figure 7b also shows significantly different gait patterns between those two subjects. However, the variance in the y-direction is larger than that in the z-direction (Figure 7b). The y-direction represents the up–down movement that is affected by the height of subjects. Therefore, the height of the subject is easily identified by Kinect.

CONCLUSION

Kinect with the arrangement of our gait aisle shows that an individual has a unique gait pattern toward the movement of its specific joint, such as the spine base. Kinect effectively captures two patterns in two directions, namely, the up–down movement (y direction) and right–left movement or lateral flexion (z direction). In a case of spine joint movement, two subjects are distinguished on the basis of their cyclic pattern by using a 4 m-long and 1 m-wide of gait aisle. Moreover, Kinect has an easy setup that enables us to utilize it as a medical home instrument to monitor the gait pattern of a patient.

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