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A Low-Cost Upper Limb Monitoring System for Post-Stroke Patient Using Kinect

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Abstract: Diagnosis and monitoring system is most important part of physical rehabilitation process. In this research, a monitoring system is the main concern to identify the improvement from stroke disabilities. Post-stroke patients are required to know the upper limb movement recovery status in order to check the improvement on their post therapy exercises. The movement measurement can be carried out by examining the elbow angle. This paper aims to monitor improvement of the recovery stages for stroke patient with the proposed low-cost system. The system consists of Kinect camera, PC and a software system. Kinect sensor is used to detect human skeleton for the processing of joint angular displacement. This sophisticated technology allows stroke patients to know their level of stroke by measuring the joint angular displacement and angular velocity of patient elbow movement. So, the Kinect system can be installed and used for post stroke patient upper limb movement measurement exercises. The experiment carried out by installing the Kinect V2 on the PC and set it up about 1 meter away from the subject. When the subject lifts hand, the proposed system would detect the angular displacement and angular velocity of patient's hand motion. The software will then show the improvement stages of the post stroke patient and compare the data between post stroke patient and normal person.

Keywords: Stroke recovery, monitoring, algorithm, angle measurement.

1.0 INTRODUCTION

The investigation of body joint movements is very important for the wellbeing and treatment of patients with nervous and stroke disorders. Permanent hememaresis at the farthest point due to stroke causes the blockage of real hand development. There is a permanent reduction in muscle strengthening and comparing joint torque designs due to stroke [1]. Some checks suggest that uncommon couplings of shoulder-to-shoulder elbows and shoulder abductors with elbow flexors often encourage some of the features of the developmental cliché shown by serious stroke patients [2]. In this work, continuous and successful recovery treatments are essential for screening and controlling variations from norms. There is an important need for post-clinical treatment of local rehabilitation. The marker-based framework for capturing and checking the movement of the human body, (for example, Vicon) is well-known for the furthest point recovery for their precise clinical dimension of loyalty. Therefore, lesser-bound markers to capture movement, for example, Microsoft Kinect, are practical for local recovery due to the simplicity and capability of delivering it.

There are several techniques were developed for post stroke diagnosis purpose. Magnetoencephalography (MEG) in stroke recovery and rehabilitation that is a non-invasive neurophysiological technique used to study cerebral cortex and also monitoring stroke recovery and rehabilitation. MEG not commonly use because of high cost and to develop MEG need a dedicated multidisciplinary team [3]. A real time articulated human motion tracking using tri-axis inertial/magnetic sensor package that using tri-axis inertial/magnetic sensors package. It is a precise tracking can be reached by using kalman filters. This kalman filter used to eliminate drift errors while making the angular rate measurements of the rate gyro that increases the dynamic classification and linear acceleration from the accelerometer. However, lag time is generated by kalman filters and has a conflict between lag time, reduction time altitude causes a larger random error [4]. The other technique is a real-time Decentralized articulated motion analysis and object

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tracking from videos. It was developed for Fast and easy implementation. However, it fails to provide expectation result and cannot handle pose relation between two adjacent parts [5]. Therefore, Kinect attracts to the users as a low-cost system. The exactness, legitimacy and test retest unwavering quality proportions of Kinect have been concentrated for scope of movement [6-8], postural control [9], [10] and step [11-13]. The outcomes [8] detailed demonstrate a uniqueness [14] between body joint areas seen by Kinect and that gotten by a clinical highest quality level stereo photogrammetry framework, for example, Vicon. The types of length of the body's fragment demand 6-8 cm for the arm, and 2-5 cm for the forearm are considered when using Kinect as it does not provide an anthropometric frame show [8], [15]. In addition, the mistake was observed to be bring down for abdominal area than lower body joints [8]. The execution of Kinect has additionally been concentrated for non-sound subjects [16], [17] and old populace [15]. Test results demonstrated that the precision of Kinect for estimating gross spatial development, for example, shoulder and elbow development, was higher than that for fine developments (for example, hands) [16]. The dissimilarity in body semantics [18], for example, body fragment length and introduction increment amid development.

Thus, it is required to improve accuracy of Kinect in measurements related to clinical assessment and biomechanical modeling.

2.0 MATERIALS AND METHODS

Figure 1 shows a low-cost limb monitoring system. Kinect sensor can recognize the user or human body movement with remote information from the infrared depth sensor and the normal camera attached to the Kinect device. This device can detect the body moving in 3D. When started, the image of depth can be detected by the frame of the motion capture system through the Kinect device. From the rearrangement, it knows the user body part of the mapping image. The computer can show the mapping and analyze data with a combination of skeleton tracking and then the application will store all the data collected in this project for further reference.

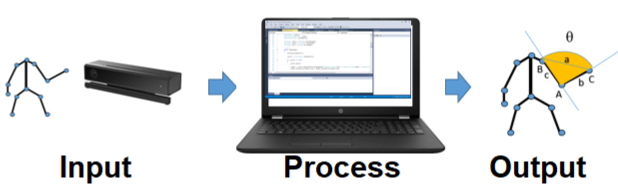

Figure 1: Diagram showing how the system works using Kinect.

There are eleven basic joints can be seen from a human body as shown in Figure 2. Using the Kinect camera, we can detect any of these angles for monitoring purpose.

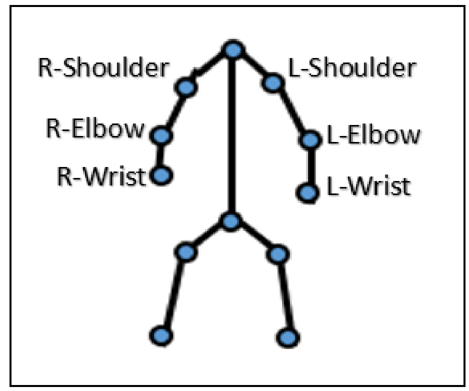

Figure 2: Upper Limb Components for Modelling

In this research we consider measuring elbow joint only from upper limb of human body. The Kinect was place 1 meter away from subjects to capture the upper limb movement. The Kinect output naturally lends itself to the use of a 3D rectangular coordinate system within the depth range of 0-10 m.

In Figure 3, wrist joint is denoted by $C(X_C,Y_C,Z_C)$ where X_C,Y_C,Z_C are the positions along x, y, z axis, elbow joint is denoted by $A(X_A,Y_A,Z_A)$ where X_A,Y_A,Z_A are the positions along x, y, z axis, shoulder angle is denoted by $B(X_B,Y_B,Z_B)$ where X_B,Y_B,Z_B are the positions along x, y, z axis. Figure 3 shows the geometry to measure angle BAC from ABC rectangle. The length of AB is c, BC is a and CA is b. The elbow angle is,

$$\omega = \frac{\Delta\theta\ (\theta_{final} - \theta_{initial})}{\Delta t\ (t_{final} - t_{initial})} \quad \ldots(1)$$

ω =Angular velocity of elbow movement in radian
$\Delta\theta$=Change of angular displacement for elbow movement
Δt=change of time for elbow to move.

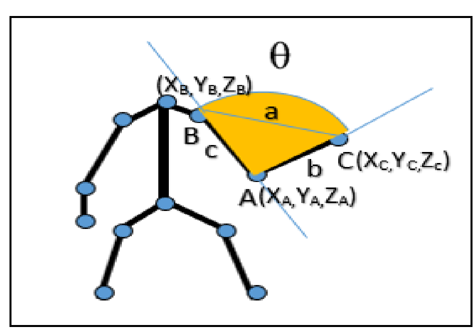

Figure 3: Measurement to calculate joint angle

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3.0 RESULTS AND DISCUSSIONS

1. Experimental Setup

Microsoft Xbox Kinect is used to measure the elbow angle in this experiment. It is composed one infrared ray depth finding sensor and one Red, Green and Blue camera. The infrared sensor in MS Kinect finds the joints 3D position using the camera coordinates system.

There are three subjects participated in this experiment and able to successfully complete several sessions of angle measurement (rad) activities. Figure 4 shows the upper limb movement and the skeleton tracer from the display unit.

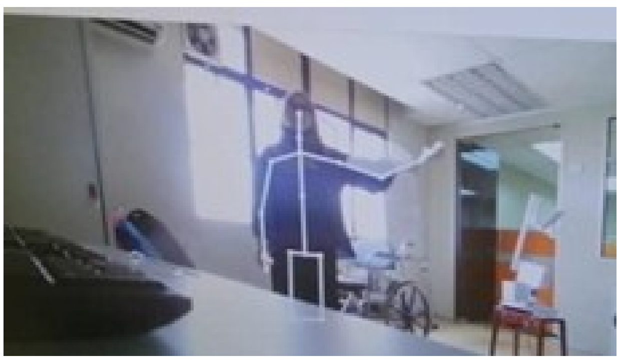

Figure 4: Measurement of the Subject 1 Flexion.

Figure 5 illustrates the angular displacement vs time measurement for subject 1. The vertical axis represents the angular displacement of elbow movement for subject 1 while the horizontal axis represents the time in second of elbow movement.

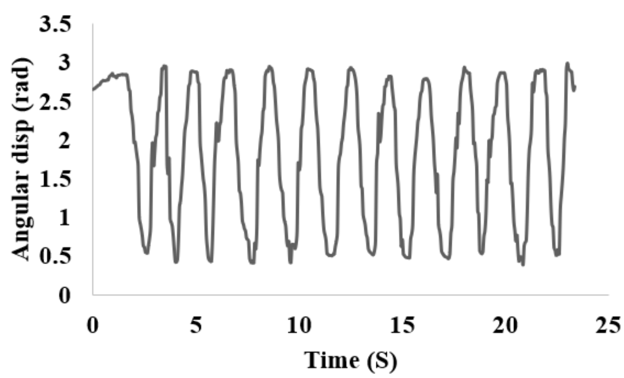

Figure 5: Angular Displacement of Elbow Joint for Subject 1

The graph shown in Figure 6 presents both the increase and decrease angular velocity constantly, as the angular velocity fluctuated starting from 0s until 23s. The lowest value angular velocity for subject 1 is 0.003776 rads-1. The maximum angular displacement is recorded 2.99 rad at 23 sec. This is because the hand is completely extended. Once the upper arm perform flexion then we recorded the minimum angular displacement which is 0.383 rad.

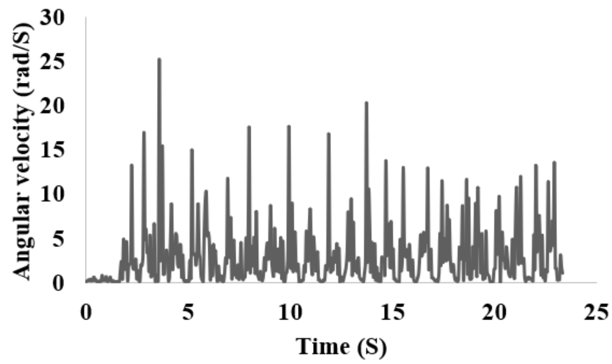

Figure 6: Angular Velocity of Elbow Joint for Subject 1.

Table 1 shows the comparison of angular data captured from the experiment. The average different time between two peaks are 1.80s, time for angular displacement peak value in between 1.3s until 2.1s. Average maximum value of angular displacement is 2.888795 rad. Maximum extended elbow for subject 1 is until 2.986 radian, which is 171.09 degree at 23 seconds. Minimum elbow flexion for subject 1 is 0.384 radian which is 22 degree during 20.85s. Average value of angular velocity peak is 1.06031 rads-1. Average different time between 2 minimum values are 1.80s, different time for angular displacement minimum value in between 1.4s until 2.02s. Average minimum value of angular displacement is 0.465189 rad. Average minimum value of angular velocity is 0.676859.

Table 1: Comparison angular data between Subjects

subject	Maximum extension of elbow(rad)	Maximum flexion of elbow(rad)	Average angular velocity for flexion (rad/s)	Average angular velocity for extension (rad/s)
Subject 1	2.986	0.384	0.676859	1.06031
Subject 2	3.141859	0.021345	5.785742	12.84773
Subject 3	3.108259	0.422816	1.056106	0.97558

Joint stiffness can be determined by the measurement from the angular velocity of a joint. The velocity of a normal joint and a stiff joint will be different. Therefore, the main focus on this experiment is to get the angular displacement and angular velocity of the subject. From Table 1, it can be seen that the subject 2 is healthier and the arm is quite normal compare the others two subjects due to the higher arm movement velocity and maximum of flexion of 0.21345 rad/s and extension of the upper arm of

3.141859/s. Thus, this analysis is considered to check the abnormality movement of the human upper limb.

5.0 CONCLUSION

This work explained the real-time angular displacement and velocity measurement method for a human elbow joint angle using Microsoft Kinect sensor. A methodology was developed and proven experimentally by applying on three subjects. During experiment, the system was run for 25 seconds and one healthier upper arm subject was also identified from three using this proposed technique.

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