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Implementation of Affordable Joint Angle Measurement for Gait Analysis using Kinect Image Sensor

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Abstract : *In this paper a affordable gait analysis system based on kinect sensor is presented. Here kinect sensor is used for acquiring skeleton data for calculating three-dimensional (3D) motion parameters. By image processing to track user movements in the skeleton frame to frame then position of the skeleton joints tracked. The lower joints position in the skeleton that reports X, Y, Z coordinates. This information is use to calculate relative angle between joints. From law of cosine measured the angle between the two joints as skeleton joint continuous tracking. Experiments performed in frontal plane of skeleton to verify the joint angle measurement efficiency of the kinect for gait analysis.*
Keywords – *Gait analysis, joint angle, kinematics, kinect sensor.*

I. INTRODUCTION

Present gait systems are more entangled and distressing to use elderly patients. Demand of portable rehabilitation system will increase due to more number of disabled. It is desired to focus on development of new gait system that will be user-friendly, low cost, and easily installable. To measure gait joint angle, different methods already exists and are largely available. A first method uses accelerometers to record dynamic of movement, for instance they can measure gait parameters when they fixed to joint segments position or to various locations on different joints [1]. Another is optical marker based systems which optical sensors placed on joint position of the body is gives the kinematic data suitable for gait analysis. These systems are wired which interfere in natural gait patterns of the subject thus questioning the accuracy of recorded data. For overcoming such problems there is a need to develop wireless and also system which does not contain wearable components.

kinect based system is presented which consists RGB image sensor, IR (3D) depth sensor etc. kinect gives 3D skeletal image of person moving within its field of view [2]. In this work, for selected joints angle measurement between joints is calculating during joints extension/flexion movements. For this the kinect sensor system is integrated with LabVIEW for work in real time environment.

II. DATA ACQUISITION

The acquisition is done in indoor gait lab. The location of kinect is set such that the subject faces the camera and the depth axis is normal to the frontal plane. Both the RGB and depth streams were recorded at 640×480 pixels resolution at a frame rate of 30 (fps). For rendering skeleton in 3D space primary skeleton array means joint position array required [3]. From reading of skeleton image gives the information of joint position and orientation in X, Y, Z co-ordinates. Skeletal 3D frames and RGB video feed are displayed in adjacent windows for better visual perception. Below Figure 1 is shown for how data acquisition and joint angle measurement is accomplished.

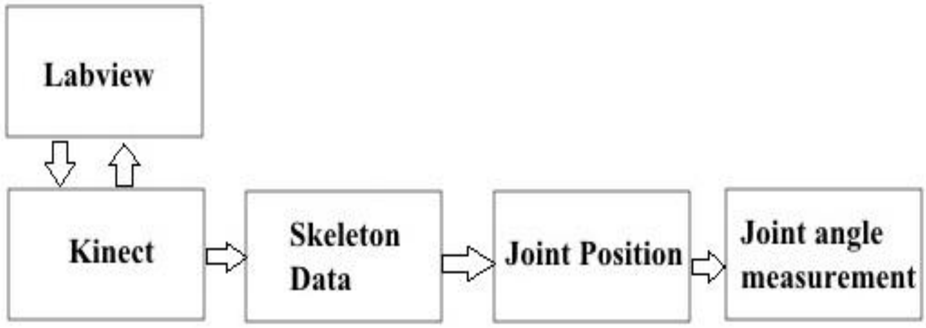


Fig 1: Data acquisition and joint angle measurement

In figure 2 mentioned the acquired RGB image and 3D skeleton view from kinect RGB sensor and IR depth sensor respectively.

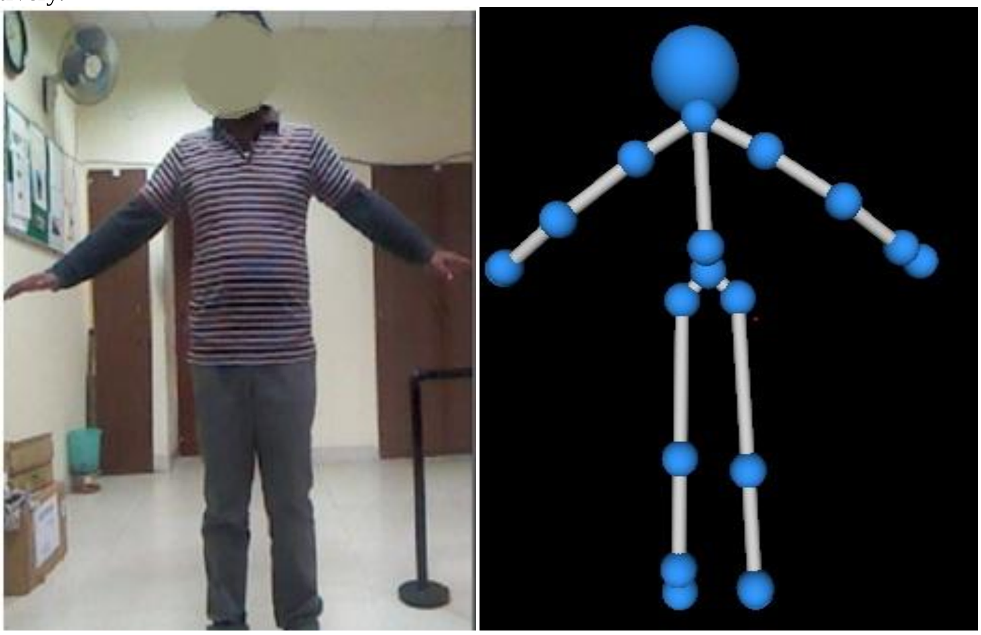


Fig. 2: an acquired sample color image and corresponding skeleton image from kinect sensor.

III. COMPUTATION OF THE GAIT ANALYSIS AND FEATURE EXTRACTION

The kinect skeleton images can give information up to 20 joints in three dimensional spaces. Here lower limb joints are considered for angle measurement. The joint angle is calculated from the coordinates extracted from the joint vertices. Euclidean distance is calculated in 3D space between lower limb joints [4]. Euclidean distance formula:

$$d(i,j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2} \quad (1)$$

The total length of selected joint segments is calculated from the sum of the following distances between joints:

Height= (d(l_ankle,l_knee)+d(l_knee,l_hip)+(r_ankle,r_knee)+d(r_knee,r_hip))/2 (2)

The averaging is performed to increase accuracy of measurement. Selected lower joints are shown in Table 1. Measuring the angle between joints i, j, k in the following way, calculating relative angles between joints required length of selected joint segments which are A, B, C respectively shown below,

$$A = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$
$$B = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$
$$C = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$
$$\theta = \cos^{-1}\left(\frac{B^2 - A^2 - C^2}{2AC}\right) \quad (3)$$

All distances are in meters, and angles in degrees.

Table 1: Selected lower limb joints

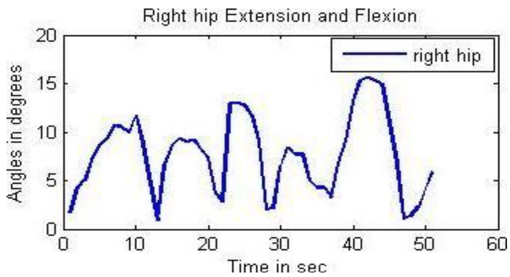
Right leg	**Left leg**
Hip Center	Hip Center
Hip	Hip
Knee	Knee
Ankle	Ankle

IV. EXPERIMENTAL STUDY AND RESULTS

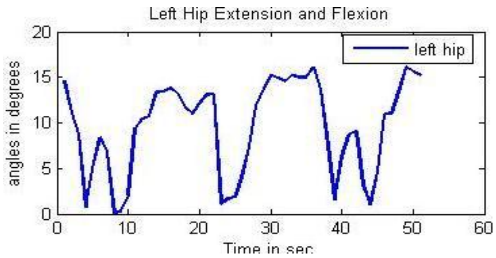
To get joint angle from skeleton data we select three joints. Between these three joints form an angle with the middle joint as the vertex. For that extracted lower joints describe in Table 2. All angles are calculated in degrees.

Table 2: Extracted lower joints for angle calculation from skeleton data.

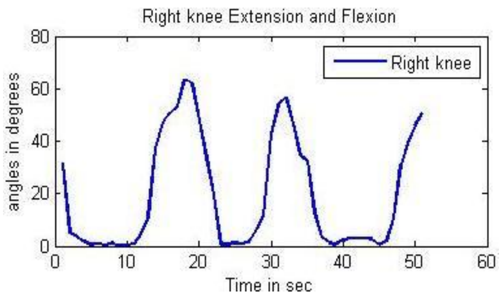
Group 1	**Selected joints**
Hip center	Right Hip and Left Hip
Right Hip and Left Hip	
Right Knee and Left Hip	
Group 2	Right Knee and Left Knee
Right Hip and Left Hip	
Right Knee and Left Knee	
Right Ankle and Left ankle	



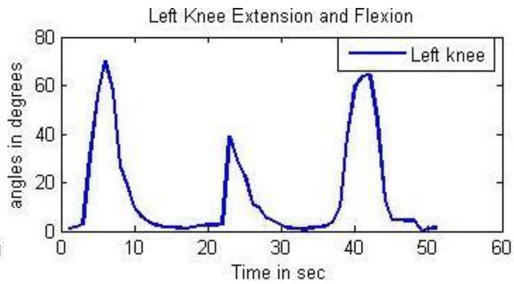
(a)



(b)



(c)



(d)

Fig 3: Measured joint angles: (a) Right hip (b) Left hip (c) Right knee (d) Left Knee in frontal plane for joints extension and flexion movement.

Study is the when knee joint extension and flexion, how hip joint extension and flexion is done, both joint angle are calculating simultaneously. After measuring joint angles for right hip and left hip ranges between 0° to 15°and right knee and left knee angle ranges between 0° to 75° in. Full range of motion cannot be detected by the system as the joint segments get overlapped after certain range of motion. This overlap causes limitation in angle measurement from a single side view. Measurement of full range of motion in joints is not possible using a single Kinect camera setup [5].

V. CONCLUSION

We discussed methods for Kinect sensor based joint angle measurement for the human gait analysis. Though a limited range of motion can be measured using a single Kinect sensor, the system can be used for limited range of motion activities like walking where a limb segment does not overlap the other when camera and subject are placed face to face. The system is also cost effective than the sophisticated systems available. As the system does not install any sensor on the subject body movement data is more reliable and natural. Future work is to calculate joint angles with multiple Kinect systems for better gait analysis from coronal, frontal, sagittal plane.

VI. ACKNOWLEDGEMENTS

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