A study on human activity recognition based on acceleration-angular velocity data and link mechanism

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1 Introduce

Recently human activity recognition and behavior analysis are often studied aiming at the service deployments to fields of the medical treatment and security. For observing human activities, previous works are basically grouped into two types of systems ; one is based on video and wearable sensors and the other is on the motion capture system designed for analyzing human joint construction. The video and motion capture system is easy to consider joint construction, but it requires the laboratory room for filming 3D data. In contrast, acceleration sensor is easily handled in sense that we do not need any other facilities. However, it can not measure joint structures and body sizes because the data obtaining from the sensor are only accelerations.

In this article we propose a statistical method of estimating displacement angle of shoulder joint based on only one acceleration-gyro sensor. We model the displacements of the angle of the shoulder joint in each movement direction of the arm and estimate the parameters of the arm by nonlinear optimization techniques. We also show that our method can give a better classification in case of applying to gym exercise.

2 Previous work

Hashimoto et al. (2008) proposed a method of estimation based on measurements of range of upper limb motion by using both a 3-axis wireless accelerometer and 3-axis wireless gyroscope. Kai et al. (2008) proposed a set of heuristics that significantly increase the robustness of motion sensor-based activity recognition with respect to sensor displacement. Ohmura et al .(2006) proposed a wearable sensing device called "B-Pack", which is designed to capture nursing activities in real hospital. Shimada et al. (2006) proposed a survey report for the model fitting method to estimate 3D posture of articulated objects such as human body and hand.

3 Shoulder Joint

In general, when it is measured acceleration data based on sensors, the sensor is installed on the arm. Therefor, we focus a shoulder joint because it is a basic point of arm's motion. The shoulder joint has three degree of freedom. The front back direction is motion of walking. The lateral direction is motion that sideways moves the arm. The horizontal direction is motion that the arm is sideways moved with ground while maintaining it to the horizontal. The outline chart is shown as follows.

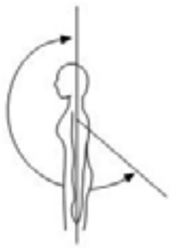

Figure 1: front back direction

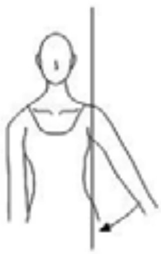

Figure 2: lateral direction

Figure 3: horizontal direction

4 Proposed method

In this section, we propose the method of estimating the joint angle to the means degree of each one.

4.1 Displacement angle of shoulder joint

Front back and lateral direction can be calculated by using the acceleration data. When calculating, the person assumes the solid body link, and calculates two dimensional displacement from a certain direction.

Front back direction(FBD) is analyzed from the movement of the arm when human is seen from side. The outline chart is shown as follows. As shown in Figure 4, when the arm is moved front back direction when seeing from the first aspect, the angle is caused between the body and the arm as shown in Figure 5. This is called angle displacement in this degree of freedom. Similarly, when the lateral direction(LD) is seen from the second aspects, the angle is caused between the body and the arm as shown in Figure 6.

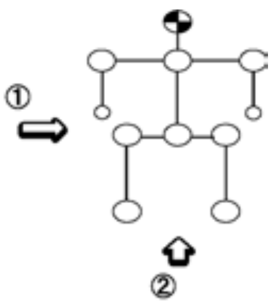

Figure 4: link model

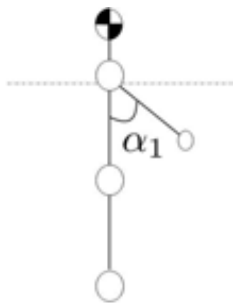

Figure 5: angle of FBD

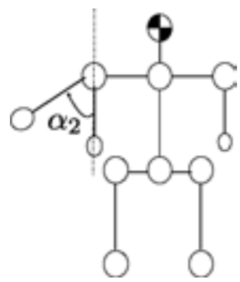

Figure 6: angle of LD

The angle of displacement FBD and LD can be calculated based on link model shown as Figure 4. Takeuchi et al. (2008) describes that angle between axes of sensor and ground can be calculated by using gravitational acceleration. When assuming the parameter where i shows the axis, the angle becomes the following expression.

$$(1) \qquad \theta_i = \sin^{-1} \frac{a_i}{\sqrt{a_x^2 + a_y^2 + a_z^2}}$$

For example, if the axis of the acceleration sensor is taken into consideration, FBD becomes the following link models. Figure 7 is describing the direction of the 3-axis of acceleration sensor. y axis is the horizontal relation against the frame of the arm. Therefore, if the arm is moved to the front, the direction of y axis is shown in Figure 8.

Figure 7: direction of 3-axis

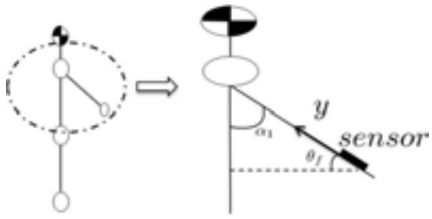

Figure 8: link model of FBD

Assuming the angle between ground and y axis to be θ_f, the angle of shoulder joint disignated as α_1 can be calculated following expression. It is possible to calculate by similar techniques.

(2) $$\alpha_1 = 90 - \theta_f$$

4.2 The horizontal angle displacement

The horizontal angle displacement cannot be calculated by using expression (1) because a displace of gravitational acceleration is very small. Figure 9 and Figure 10 show the displacement of the gravitational acceleration when the arm is moved "front and back direction" and "horizontal direction".

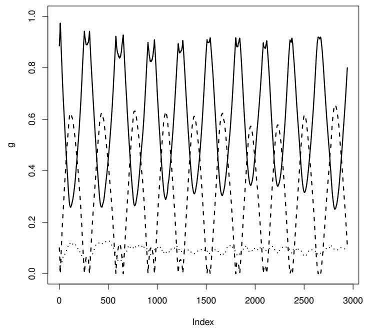

Figure 9: displacement of FBD

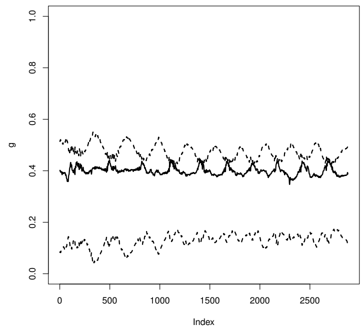

Figure 10: displacement of HD

We propose the method of estimating the horizontal angle displacement by a nonlinear optimization technique this time.

Considering that human's arm is solid body link, the model with the arm is expressed in Figure 12. Figure 12 is showing of Figure 11 in figure of an easy link. r is the distance from the center of shoulder joint to the installed sensor. The joint angle is assumed to be α.

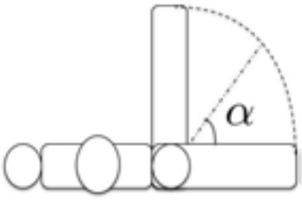

Figure 11: horizontal model

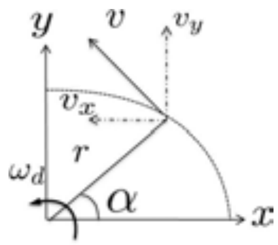

Figure 12: link model of horizontal

In the coordinate system in Figure 12, let the sensor velocity to be v, and the resolution element is defined as follows.

$$v_x = -r\sin(a\alpha + h_1) + c_1 \qquad v_y = r\cos(b\alpha + h_2) + c_2 \tag{3}$$

In the present study, the unknown parameters is estimated by applying it to the speed data obtained when actually moving in the model of expression (4) defined by using expression (3). The parameters a and b are concerning the frequency, and h_1 and h_2 are concerning the phase, and c_1 and c_2 are concering the position.

$$\sum_{i=1}^{N}(v_i - \sqrt{2r^2\sin^2(a\alpha_i + h_1) + 2(c_2\cos(b\alpha_i + h_2) - c_1\sin(a\alpha_i + h_1)) + c_1^2 + c_2^2})^2 \to min \tag{4}$$

5 Verification experiment

In this section, we conducted an easy experiment to check the performance of the proposed method.

The testees wear the acceleration sensor in the humerus, and the arm is moved in the direction of the means degree of each one. They move arms along the specified direction lines repeatedly from 0 to 90 degrees while extended. The displacement of the angle of the shoulder joint when the proposed method was applied to be obtained data was calculated, and the utility was examined.

6 Result of displacement angle

The displacement of the angle of the joint in the direction of the means degree of each one which obtained it by the experiment is shown below.

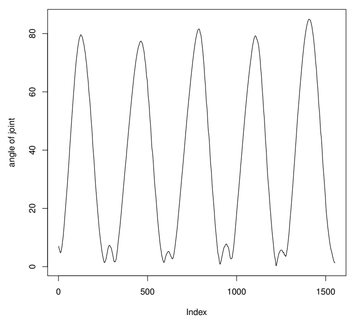

Figure 13: joint angle of FBD

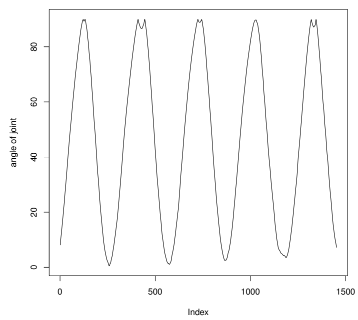

Figure 14: joint angle of LD

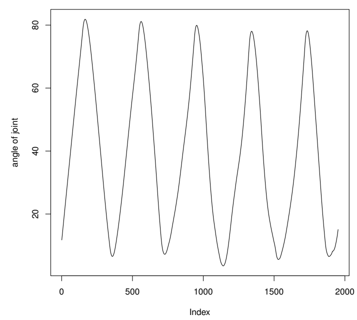

Figure 15: joint angle of HD

We were able to extract displacements of angles from 4 degrees in minimum to 86 degrees in maximum. There are individual variation within the range to move arms, and them to measure the angle displacement accurately becomes difficult.

6.1 Usefulness the proposed method

In this section, we examine the usefulness the proposed method comparing the angle of displacement using the proposed method is applied and angle of displacements obtained by the motion capture system. For example, a result of front back direction and horizontal direction graph is shown.

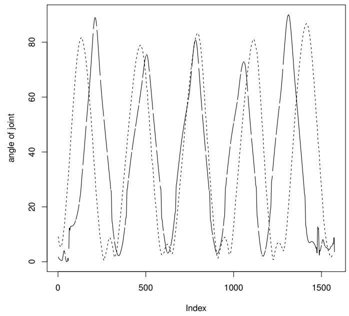

Figure 16: result of FBD

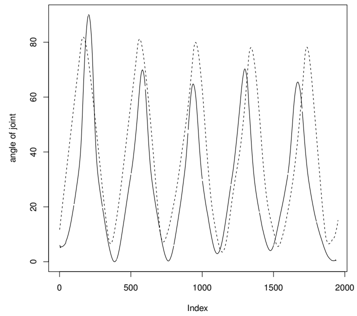

Figure 17: result of HD

In both graphs the dotted line indicates the proposed method results and the solid line indicates the results obtained from the motion capture system. A movement frequency and rough angle displacement can be estimated though a detailed scale is different. The more accurate displacement estimates may be obtained by constructing another model with three dimensions, which is a very interesting subject of inquiry in the future.

7 Discussion

In our experiment we designed five models of gym exercises, and each exercise consisted of ten repetitions. We extracted the summary statistics from acceleration data and angular velocity data. With support vector machine we could derive the angle displacements as features that characterise the gym exercises. The result of computation showed high performance of recognition rates.

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