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Motion Analysis and Recognition Using Principle Component Analysis and Angular Velocity

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Abstract

Abstract: Wearable sensor based and vision based are the two common methods used to analyze motion. These methods mainly used in medical and sports field where the study of body parts is crucial. In this study, 3-space sensor was used to collect the data of walking and jogging motions of subjects. Angular velocity was proposed as the component to recognize human motions. The data were processed by Principle of Component Analysis (PCA) and recognized by MATLAB functions. PCA was used to reduce and categorize the data into the respective principle components for recognition. Vectors were generated in the system to re-present the motions of the complete recorded activities. The proposed motion recognition system achieved more than 85 % of accuracy.

Keywords: *Accelerometer, angular velocity, motion recognition, PCA.*

I. INTRODUCTION

Gait analysis is a study about movement of animal, or in other words, a study of animal locomotion, which is also implemented on human in order to analyze human gait, that is widely used in medical purpose. This implementation is crucial to illustrate the different body dynamic which depends on the test subjects' conditions, as stated in [1]. Gait analysis can be done by two major methods, namely, wearable sensor based and vision based.

II. RESEARCH REVIEW

There are advantages and disadvantages for wearable and vision based methods. The vision based use camera to capture the motion of the test subject, since then will consume higher cost in preparation of the equipment. Furthermore, this technique normally utilizes more than one camera to capture the motion in 3D dimension perspectives (because one camera can only capture a motion in 2D) [2]. The allowable movement spacing of the test subject is limited to the capturing radius of the camera, since the camera is fixed in one place. Therefore, treadmill is the proposed method to solve this situation by ensuring the subject is not moving out of the capture range [3]-[4].

For wearable sensor based, [5] use miniature wearable sensor gyroscope to detect any dysfunction in walking motion of a patient through stairs climbing. This experiment is quite impossible to be done by vision based, however, it can be done easily by wearable sensor based. Another common application using the wearable sensor method is to identify gait event of a test subject [6]-[8]. This application generally carried out by using the force plate and at least two force plates are required to get the timing of a complete stride of a motion. Due to its immobilize characteristic (force plates is not portable because they are mounted at the floor), gait recognition research need to search for another alternative, which is wearable sensor that can provide a large number of strides of the motion for analysis, as stated in [9]. Besides, [10] show that the wearable sensor is able to

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provide promising clinical capabilities in studying of Parkinson's disease and [11] for studying patients with knee osteoarthritis.

In all of these purposes, wearable sensor is more desirable, since the data recorded are purely from the motions. Unlike vision based method, it may records irrelevant data for instance, the shadow of the moving subject, which then will become the artifact in the data processing stage [12].

III. MATERIALS AND METHODS

A. Data Collection

The jogging and walking activities were performed on a treadmill with regular motor. The normal jogging and walking speed of every subject were pre-defined by conducting a pre-test. The subjects were asked to perform a normal jogging and walking motions pleasantly at their own pace and convenience along a 10 meters long track. Their normal jogging and walking speed were calculated by dividing the distance with total time taken. The speed was recorded as 6.3-6.7 ft/s (1.92-2.04 m/s) for jogging and 3.5-3.9 ft/s (1.07-1.19 m/s) for walking. Measurement of speed was in feet per second due to the setting of treadmill. Data acquisition was carried out in a supervised environment for start and end time stamping. The process was repeated 5 times for every motion with distance 10 meters, 20 meters, 30 meters, 40 meters, 50 meters, 100 meters, 150 meters and 200 meters.

Table I shows the data collected and further distributed for recognition purpose. The data were manipulated and tested in three testing categories (data, combined and large & combined as shown in Fig. 6). Data testing represents the classification of walking and jogging data from 10 m until 50 m respectively. Combined testing means combination of different size of sample from 10 m until 50 m for walking and jogging, while large & combined means the combination of data from 10 m to 200 m.

Table I: Data collection and distribution for recognition

Data (m)	Activity (sample)		Repetition	Total Sample	
	Walking	Jogging		Walking	Jogging
10	80	45	5	400	225
20	160	90	5	800	450
30	240	135	5	1200	675
40	320	180	5	1600	900
50	400	225	5	2000	1125
100	800	450	5	4000	2250
150	1200	675	5	6000	3375
200	1600	900	5	8000	4500

B. Angular Velocity

PCA was used in computing angular velocity of a motion. PCA aims to realign the arm rotation graphical plot to a better view since the rotation of the arm during performing activities was not perfectly and ideally along Y-axis only as shown in Fig. 1.

No single human is able to perform a perfect and ideal arm rotation during activities due to wind resistance, clothes rubbing and physical or emotional effect. The rotations of arm along other axes due to disturbances were eliminated by PCA. PCA was used to realign the view focus on the desired axis.

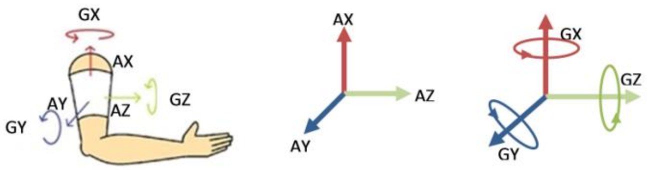

Fig 1: Rotation motion of test subject's arm.

Angular velocity was chosen as the component to differentiate human jogging and walking motions [13]. Swinging of arm in anti-clockwise is called as positive angular velocity and vice-versa. Fig. 2 shows the positive angular velocity with anti-clockwise rotation. This method was proposed based on the ergonomic and kinematic of the swinging arms during walking and jogging motions. The existing researches on motion classification are mainly performing by using artificial intelligence for pattern recognition. This method needs large number of dataset for training and thus increase the computation cost. Conversely, the proposed method is depending on the computation of the velocity vectors values.

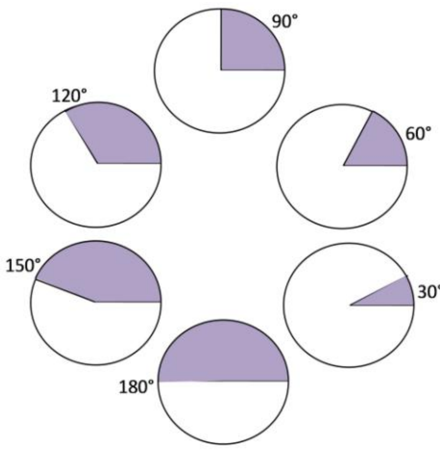

Fig. 2: Angle of rotation.

C. Principle of Component Analysis (PCA)

Principle of component analysis is a procedure in analyzing two or three dimensional set of data, or to minimize the number of data by creating an artificial point to represent the set of data [14]. Since the data collecting process was repeated for 100 times, the scatter plot graph will has 100 points and each point is representing three aspects (acceleration, angular motion and angle) for one data collecting event, as written in [15]. Several steps are needed to be done such as computing the covariance, covariance matrix, Eigen vector and Eigen value to generate an artificial point for a set of data. The flowchart of the system is shown in Fig. 3.

PCA was used to reduce the dimension of the data, since the sample collected for a normal walking activity with 10 meter long is around 80 data. The data captured by the sensor are further categorized into acceleration in three axes, gyro motion in three axes and angle in three axes. Therefore, the collection of data is very huge. In order to reduce the complexity, PCA was used to extract the significant dimension for further analysis and clustering.

The clustering of motion is based on the threshold value as shown in Table II. The determination of a certain motion is based on the minimum and maximum values of the respective motions. The flow in Fig. 3 describes the step in clustering a motion starting from the PCA for dimension reduction until the value that fulfill the threshold of “walking”, “jogging” or classifies as “unidentified” for out of both thresholds.

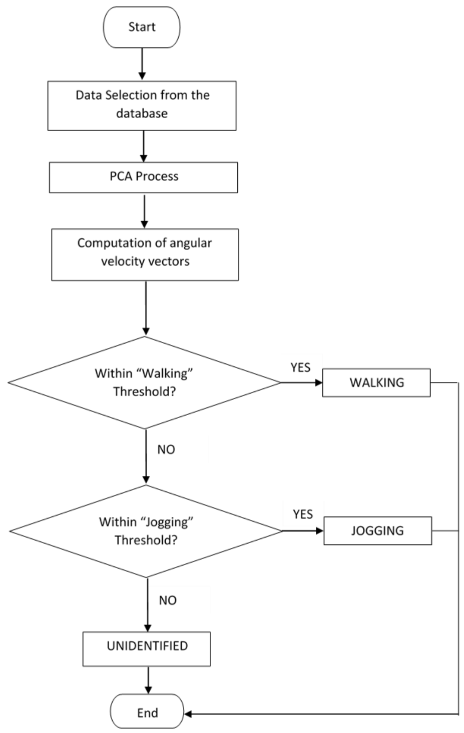

Fig. 3: Flowchart of the recognition system.

IV. RESULT AND DISCUSSION

Angular velocity is the proposed main component to recognize a recorded data from wearable sensor. Fig. 4 shows part of the result with 200 data (50 for jogging for each subject and 50 for walking for each subject) from two subjects that being analyzed by the developed system.

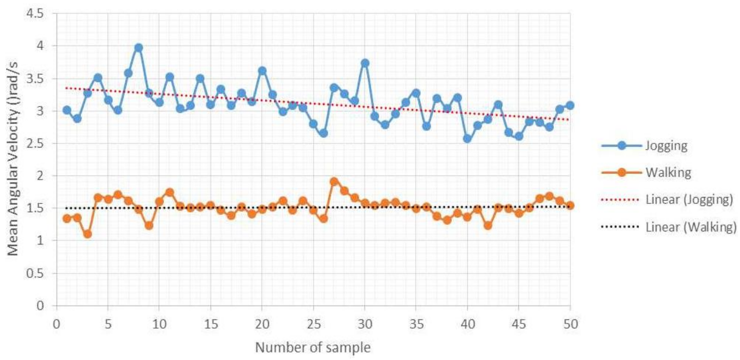

Fig. 4: Ranges of mean angular velocity for jogging and walking motions.

A. Angular Velocity

Based on the value of mean of angular velocity of test subject's arm in Fig. 4, a range is produced in order to create a program to detect and recognize test subject's motion. Ranges of mean of angular velocity of the test subject arm while walking and jogging are

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tabulated in Table II.

It is observed that, the angular velocity of test subject arm is faster in jogging compared to in walking. It means that test subject swing their arm faster in jogging compared with walking. Since the range of angular velocity of walking and jogging are not overlap with each other, this ranges can be used to recognize and differentiate walking and jogging motion.

Table II: Ranges of angular velocity of walking and jogging motion

Angular Velocity (rad/s)			
Walking		Jogging	
Min	Max	Min	Max
1.101	1.912	2.570	3.966

B. Differentiating Motions

Fig. 5 shows the final framework of the proposed human gait analysis system. The proposed system consists of three graphical plots, gyroscope best view display, acceleration gait display and the acceleration vector display. The first plot displays the best view of gyroscope after PCA process, the middle plot displays the acceleration motion vectors or quiver of the data and the right plot displays the animated movement of jogging and walking motion. The mean angular velocity and mean leaping angle are displayed at the bottom with the most right display is the final classification motion. The proposed system will display "JOG" for motion recognized as jogging and "WALK" for motion recognized as walking. The word "UNIDENTIFIED" is displayed when the proposed system is unable to process or analyze a certain input data.

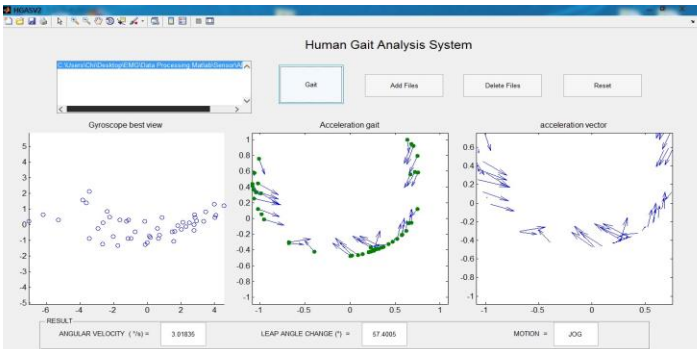

Fig. 5: Ranges of mean angular velocity for jogging and walking motions.

Fig. 6 concludes the overall results presented in bar chart and line chart. The results show that the proposed system is capable to achieve higher accuracy rate for larger sample data size. The overall performance of the proposed motion analysis system achieved is more than 85 %.

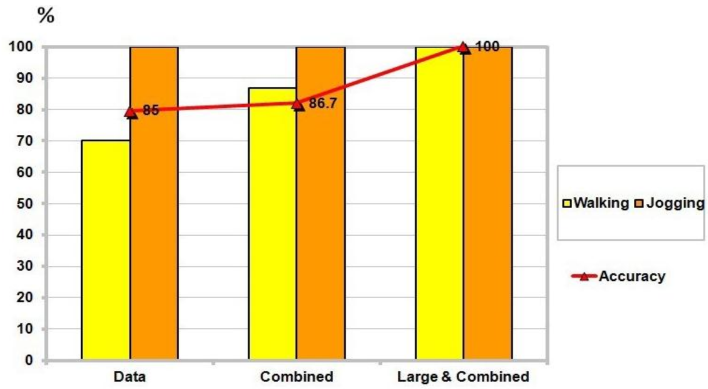

Fig. 6: Performance of proposed system based on the data size for jogging and walking activities.

V. CONCLUSION

The acceleration motion vectors or quiver plot is an enhancement of ordinary scatter plot. The ordinary scatter plot was realigned using PCA for the best view and displayed significantly the changes of motion vectors in order to present the movement in detail for every second. Quiver plots in addition display also the increment and decrement of the vectors directions and therefore, the movement is properly displayed with swinging motions for jogging and walking activities.

The angular velocity is the main components to determine jogging and walking motions. Both motions are differentiated easily based on the collected sample, where large sample data is used as guidelines. Apart from this, the minimum data size must be at least 4 times larger (around 40 meters) to achieve 100 % recognition accuracy. In other words, the performance of the proposed system is able to achieve 100 % of recognition rate if the input data size of the activity is more than 40 meters of duration.

Overall, the proposed motion analysis system achieved more than 85 % for small sample size and 100 % for sample size 4 times larger. The proposed system is managed to display the movement with animated view in terms of increment and decrement of direction of a swinging arm. Apart from this, the proposed system is capable to trace any tiny

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upper-limbs movement accurately. The tracing marks are shown in an animated plot afresh according to the original drawing sequences.

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