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Physical rehabilitation assistant system based on Kinect

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Abstract

In this paper, we present a physical rehabilitation assistant system based on skeleton detection with Kinect. The users do not have to install the detectors on the exercise equipment anymore. And then, they can just use the rehabilitation equipment with Kinect using the skeleton detection technique. In this study, we build a normalized three-dimensional Cartesian coordinates location of correct postures under OpenNI system. We find out 15 human skeleton joints with three dimensional coordinates and calculate the feature values, than we use support vector machine (SVM) as classifier to define the accuracy of posture. Finally, the system can judge the correct degree of user's postures. Also, we can have the rehabilitation purpose.

1. Introduction

The application of the Image processing makes the development of the technology more life-oriented, and there are the wide varieties of the software to capture the images. Kinect is the popular device in these days, and it uses the infrared ray to build the Image depth information. Using the image in medical assistance is also a popular topic now. For example, Chen [1] mentioned that using face orientation in face images to help the vestibular rehabilitation. Yeh [2] provides three kinds way to operate the communication aid, contain movements of their arms, open and close their mouths, and eye blinks to build the Human-Computer Interface. Those two theses are the good examples of the image technique apply to the medical.

Traditionally, the rehabilitation related equipments for physical are very expensive, and users have to put on the considerable numbers of sensor, it is quite uncomfortable for the users. However, the price of the Kinect is acceptable, and the skeleton detection technique is accurate. Most important of all, users do not have to put on the sensors on them. It is quite acceptable and comfortable for the users, and it also can promote this rehabilitation system to the home life. Therefore, we purpose to recognize human posture and correct user's action for rehabilitation process. So, how to seamlessly track and successfully is very important. Kinect is a good tool to tell the human acting, the character of skeleton tracking system is not affecting by illumination, and use depth image to individual object from environment also provide the information what we needed quickly for our work.

Huang [3] using the horizontal and vertical projection, star skeleton, neural network and similar feature process techniques to recognize the five human postures, its advantage is apply to different indoor environment and different distance between human and Kinect, also can stable and real-time to recognize different human physiques. But can't to recognize more detail human posture such as wave hand, head movement. Wu [4] establishes a motion model of view-Invariant and training samples by K-means and calculating the three dimensional distance between fifteen points to matching samples, its advantage is high average recognize similarity and real-time, but only can recognize one motion. Wang [5] use three-dimensional coordinates to classify under Support Vector Machine (SVM) [6],

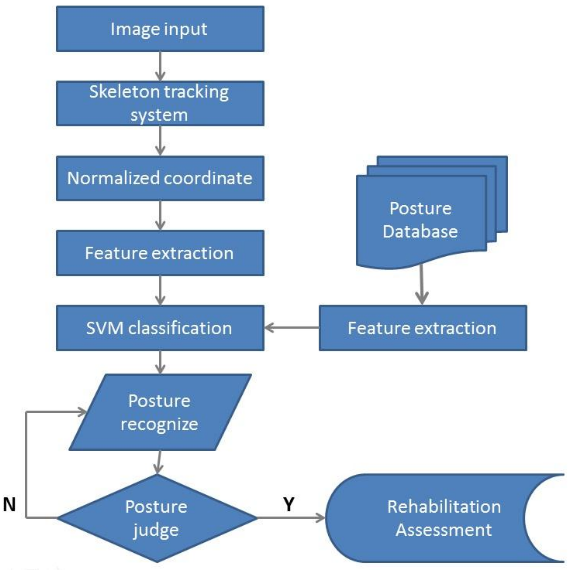

Fig. 1 The flow chart of the proposed system

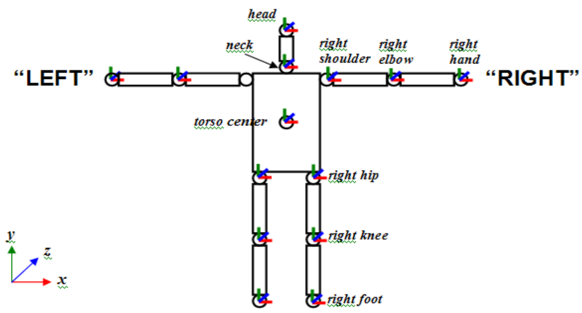

Fig. 2 The OpenNI defined the human skeleton and 15 joints from Hersy's Space

and its experiment result is almost perfect, its average recognition rate is 95.6%, but they need to use very expensive equipment to achieve goal. We combine SVM with Kinect skeleton tracking system under OpenNI [7]. Therefore, not only could make the system equipment low cost but also improve the disadvantage of user restriction.

In this paper, we recognize the human action to build an assistance system for medical rehabilitation. During the rehabilitation process, the patients need to do the same motion repeated in a long period. After the patients are discharged from hospital, they cannot make sure to do the right medical rehabilitation postures without the help of the professional medical staff. Finally, our goal is to use simple equipment to help those patients who needs physical rehabilitation.

2. EXPERIMENT

2.1. System flow chart

We set up a system based on Kinect skeleton tracking under OpenNI. First, the user go into the region of Kincet and start to skeleton tracking. And then we normalized the coordinates to change the center from the origin to the torso center. So we can calculate the feature value of 45 human joint coordinates for SVM to classify. After SVM training we set up the correct posture sample database for rehabilitation. According to the posture sample before we trained by SVM, we can recognize the user posture immediately and use human skeleton joint coordinates to correct posture. The flow chart of our system shown in Fig. 1

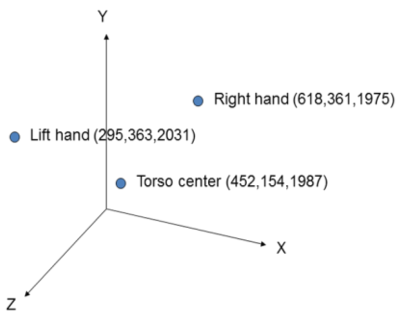

Fig. 3 The illustration before normalizing

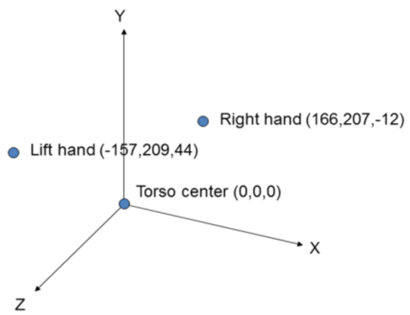

Fig. 4 The illustration after normalizing

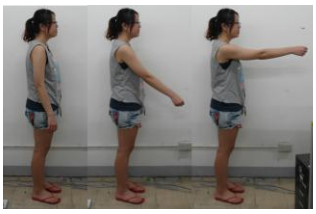

Fig. 5
The first motion

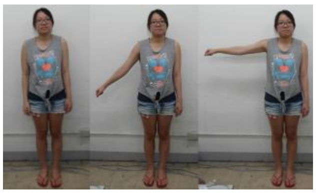

Fig. 6
The second motion

Fig. 7
The third motion

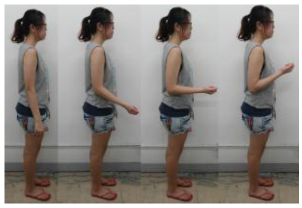

Fig. 8
The fourth motion.

2.2. Skeleton tracking system

The OpenNI defined 24 joints, but actually we can only use 15 joints to analyze skeleton by middleware. Fig.2 shows that we capture the information of skeleton by using User Generator, Depth Generator and Skeleton Capability, etc.

According to the definition of OpenNI, the user must stand in the view of Kinect and do PSI showed in Fig.2. Then we can not only locate the position of human body but also calculate the 3D coordinates (position) and the probable direction (orientation) of the 15 joints.

2.3. Normalization of coordinates

Because OpenNI's origin is Kinect in the ground truth of three-dimensional Cartesian coordinates. However, people can stand at any position in the real application. For classification, it will be a little trouble to set the value of feature. Therefore, we need to normalize the coordinates to express the skeleton system by Homogenous Coordinate System [8] in the training process. So the system will calculate the translation of the geometry conversion in 3D Cartesian coordinates and define the torso as the origin.

Fig. 3 shows the coordinate before normalizing with the torso center, the left hand and the right hand. Fig.4 shows the coordinate after normalizing.

2.4. Feature extraction

Based on the above method, we can get a normalized coordinates. According to normalized coordinate, each joint to torso center defined that as feature vector, we consider the 45 3D coordinate values $(x^{'}, y^{'}, z^{'})$ as our input data (feature points).

2.5. SVM classification

In this part, we consult the professor Lin's LIBSVM at National Taiwan University. And the parameter used in SVM are c=1, gamma=1. In the system, we design the procedures by the reality rehabilitation posture. In the training procedure is the every training movement, and then we estimate them. We use five people to be the sample. Their height are respectively 153cm, 163cm, 168cm, 174cm, and 180cm. Then they do the four movements. We took everyone for ten picture based on the same posture. After that, we got 800 databases. The figures show the training motion.

We divide one motion as 5 postures according the angle as the table 1, and the number behind the angle is the label. The first motion at 0∘, the second motion at 0∘ and the fourth motion at 0∘ are the same movement, so they have the same label. Also, the first motion at 90∘are the same movement with the third motion at 90∘.The second motion at 90∘are the same movement with the third motion at 0∘.Therefore, the total number of the labels is 16.

2.6. Posture judge

The SVM will normalize all the data from each label dataset. Then we can find the nearest training posture label for each frame in the time. But it may have some error in the result. Therefore, we add the movement judgement in the system for getting the correct experimental results. The followings are the movement judgement :

First posture: the X-axis value of the right shoulder and the right wrist must be smaller than 5 cm. Also, the X-axis value of the right wrist and the right hand must be smaller than 5 cm.
Second posture: the Z-axis of the right wrist and the right hand must be smaller than 10 cm (the arms are parallel with the body).
Third posture: the difference between the Y-axis value of the right hand and the right wrist and the Y-axis of the right shoulder must be smaller than 10 cm (make sure that move parallely).

Fourth posture: the difference between the Z-axis of the right wrist and the Z-axis of the right shoulder must be smaller than 5 cm (make sure that the arms are vertical).

2.7. Rehabilitation Assessment

In our system, the rehabilitation assessment is that the user does the movements and start from the first segment. As the Fig.9:

In the Fig.9 the number are presented as follows:

(1) The evaluation of the joint activity.
(2) The evaluation of the coordination.
(3) The evaluation of the muscular endurance.

We will record the user’s maximum joint point. And offer the average movement distribution. When reach the maximum angle, the time after finishing the movement is the evaluation of the muscular endurance.

Table 1 The movement segment.

motion	1	2	3	4
Angle 1	0∘(1)	0∘(1)	0∘(9)	0∘ (1)
Angle 2	15∘(2)	30∘(6)	30∘ (10)	15∘ (13)
Angle 3	30∘ (3)	45∘ (7)	60∘(11)	45∘(14)
Angle 4	60∘ (4)	60∘(8)	90∘(5)	90∘ (15)
Angle 5	90∘ (5)	90∘(9)	120∘(12)	120∘(16)

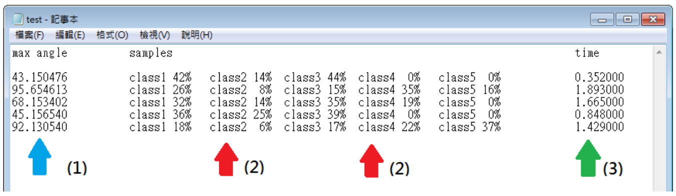

Fig. 9 The rehabilitation assessment

3. CONCLUSIONS

The input RGB and skeleton images size are 640x480 pixels, the hardware used are Microsoft Kinect, CPU Intel® Core(TM)2 Duo CPU 3.00GHz,and RAM 3GB. And software used are Microsoft Visual Studio 2010, Microsoft Kinect for OpenNI，openCV2.3,and LIBSVM. Our system process speed is 25 FPS.

In our experiment, we hire ten people to be the tester. Thy do the movement after dividing the angle to Kinect and then test it respectively. Everyone do the sample postures (16 labels) 20 times respectively and record them to forecast the results. The number of the results is 3200. And there are 3126 correct results, so the average accuracy is 97.68%. Most of them are almost 100%, but the first motion in 15∘(86.5%) and the fourth motion in 15∘(90%) are similar to be easy to recognize fail.

After testing the continuous movements, we ask the same ten people to do the test. They do the same movement from the first segment to the fifth segment respectively. In the end, they do the first segment to be the one movement and record the recognition rate as follows:

Table 2 The recognition rate of rehabilitation motion.

	Posture 1	Posture 2	Posture 3	Posture 4	Average
Success	171	197	200	179	186.75
Fail	29	3	0	21	13.25
Recognition rate	85.5	98.5	100	89.5	93.37

At first, we use the SVM to training the samples of the correct postures and use it to build a correct sample database. After training, our system for classify we take the feature value of every frame and use the SVM to match with the samples, and it can tell the accuracy of those postures. Apply this system to the rehabilitation assistances, the user can make the correct postures which are required by rehabilitation program through this simple convenient equipment. The user do not need accompany with the medical personnel to do the rehabilitation program, it can reduce some waste of the medical human resource.

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