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Kinect-based Physical Rehabilitation System for Home Use

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Abstract – *This paper represents design and development of a Kinect-based physical rehabilitation exercise monitoring and guidance system. The patient who has suffered from certain injury or disability often has a negative effect on normal day-to-day activities. Those people required rehabilitation process to monitor and exercise to make to fit. In rehabilitation center the cost of rehabilitation process is very high per session. This paper presents a concept to employ the Kinect system to support the patient during physiotherapy exercise at home. The purpose of this system to provide feedback to the user on the correctness of their exercise performance through visual aids and prove that Kinect could be effectively made use in the stream of medicine and treatment program.*

Keywords *–Microsoft Kinect sensor, Human Skeleton, Physiotherapy.*

I- INTRODUCTION

In preventive and rehabilitative healthcare, physical exercise is a powerful intervention [1]. Physical practice is important for those people who are not able to perform their routine activities due to injury, disability or any other reason. Consequently, in rehabilitation center the physical therapist identifies the problem and needs of the patient and they designed therapeutic exercise program for individual patient to achieve satisfying results, the patient has to perform the exercises on a daily basis. However, a program may require in the range of thousands of practice repetitions, and many people do not adhere to the program or perform their home exercises incorrectly, making the exercise ineffective, or even dangerous [2]. Additionally, the patient needs to pay close attention to both the body posture and the range of motions, repeating the exercises the exact same way as shown by the therapist to prevent unnecessary strain to the joints and muscles, possibly leading to further injuries [3].

There is no accuracy of doing free-hand exercise prescribed by physiotherapy doctor. But this exercise program acted of problems such that-

- The patient does not receive any feedback whether he does correct or not of prescribed practices.

- The rehabilitation process as per session is very costly and it varies the type of injury and treatment received in rehabilitation center.

Combining a computer with the Microsoft Kinect system would allow producing a physiotherapy system for home use. Correct adherence to supplemental home exercise is essential for safe, effective, and efficient rehabilitation care [1]. With Kinect solution, physiotherapist will be able to work more efficiently and patients will be more motivated. Windows PC connect with Kinect sensor which is used by both therapist and patients. Kinect sensor camera is more suitable for rehabilitation process because:

- Data about the quality and quantity of each practice performed would be recorded so that the therapist could review the patient's progress.

- Microsoft Kinect is an inexpensive device, but has the potential to provide accuracy sufficient for clinical practice.

The system allows the patient to study the prescribed exercises, and the therapist to examine the patient session in detail. The algorithm developed to track the joints of human skeleton with depth camera. The physical rehabilitation system is used by both physiotherapist and patient. The system is more convenient for patient to practice at home, which would minimize the trips to a therapy center. The Kinect-based rehabilitation system is more convenient than other system.

II- LITERATURE REVIEW

A beta Kinect-based virtual training system that might be an assistive tool and an alternative method to traditional face-to-face rehabilitation intervention. With the system, patients can perform rehabilitation at home reducing the need for clinic visits [11]. An action tutor system which enables the user to interactively retrieve a learning exemplar of the target action movement and immediately acquire motion instructions while learning it in front of the Kinect. The proposed system is composed of two stages. In the retrieval stage, non linear time wrapping algorithms are designed to retrieve video segments similar to the query movement roughly performed by the user. In the learning stage, the user learns according to the selected video exemplar, and the motion assessment including both static and dynamic difference is presented to the user in a more effective and organized way, helping him/her to perform the action movement correctly [4].
A system for medical rehabilitation of patients suffering from shoulder injuries. Hidden Markov Models (HMM) for recognition and a histogram-based comparison for computing the accuracy score. The Microsoft Kinect sensor is used to obtain 3D coordinates of human joints. Important features are extracted from the skeletal coordinates which are then quantized into 16 intermediate upper-body poses The temporal patterns of these upper-body poses are modeled by training an HMM for each exercise [5]. A new superpixel-based hand gesture recognition system based on a novel superpixel earth. Mover’s distance metric, together with Kinect depth camera. The depth and skeleton information from Kinect are effectively utilized to produce marker less hand extraction [6].

Real-time 3D computer vision-aided system applied to the monitoring of psychomotor exercise is proposed. The system is intended for the assessment and evaluation of body scheme dysfunction and left-right confusion [7]. A Kinect-based rehabilitation system for the patient with movement disorders by performing the Tai-Chi exercises at home. A baseline/intervention strategy to assess the effectiveness of this system. From the experimental results, it is shown that two patients have significantly improvement in performing the Tai Chi exercise. This system is a prototype [8].

III- BACKGROUND

Kinect sensor works as a Hardware. In this section, the information regarding Microsoft Kinect sensor are as follows:

Microsoft Kinect sensor

The Microsoft Kinect sensor is a compact system which was first released in 2010. The device contains RGB camera, an infrared emitter, a multiarray microphone, a depth sensor which acquire depth images. Based on the depth information it tracks movements of human extremities by computing the location of various skeleton joints. The 3D positions skeletal joints can be obtained in streams of skeletal frames real-time. Hence, Kinect has been used in areas far beyond console games [10]. The arrangements of the system may be connected to PC or laptop via USB and is operable with machine learning program.

The most interesting data supplied by Kinect (and its Software Development Kit (SDK)) are the skeletal data, which can be obtained by enabling the skeletal data stream and by registering an event handler to receive and process skeletal frames [1]. It can track 2 players at once so that 6 players proposed per Kinect. The Kinect can recognize user who is standing between 0.8 to 4.0 meters away (2.6 to 13.1 feet). Each fully tracked user, the 3D positions (X, Y, Z) of up to 20 joints are reported, including head, shoulder center, left/ right shoulder, left/ right elbow, left/ right wrist, left/right hand, spine, hip center, left/ right hip, left/ right knee, left/ right ankle, and left/ right foot. The X axis of the joint will change when the joints move from the right side to the left side or vice versa, while the Y axis will change when the joints move in the upwards or downwards direction. Similarly, Z axis will change when the joints move forwards or backwards in relation to the Kinect sensor [9].

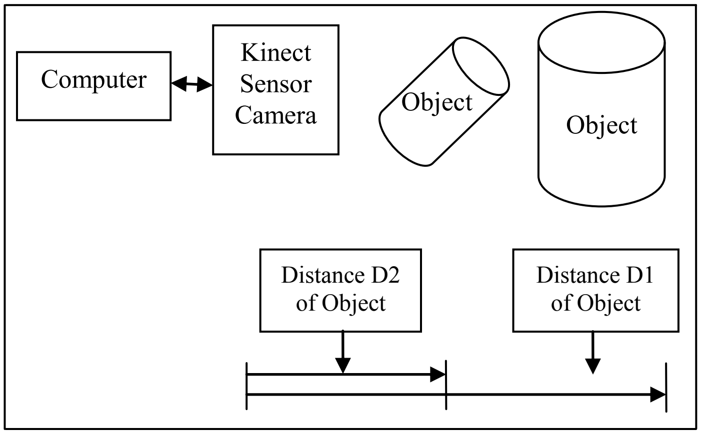

Fig. 1-The distance measured between Kinect and object

The Kinect depth sensor camera calculates distance based on the true distance between object and sensor. When there is a pixel in any of the diagonal view of the sensor, it internally draws a line that is perpendicular to the sensor and then works out the distance directly from there.

IV- SYSTEM DESIGN AND METHODOLOGY

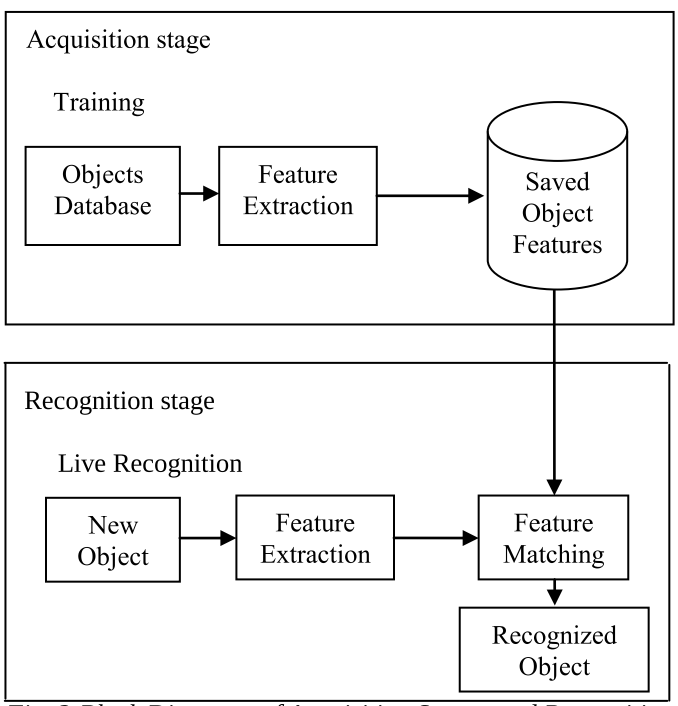

Fig. 2-Block Diagrams of Acquisition System and Recognition System

From the user point of view, the proposed system is operated through two stages. First stage is acquisition stage and second stage is recognition stage. The aspects of these two stages are illustrated with the help of Fig. 2.

The proposed solution, consist of Windows PC connect with Kinect sensor by both physiotherapist and patient. Computer is in charge running the machine learning program. When the physiotherapist uses a program he can record the exercises the patient should perform. Here he performs the exercises in front of sensor and this system converts them into a standard machine main program. When the patient uses a system here, he performs the exercises which physiotherapist recorded and his progress recorded in database.

Using this system the user could retrieve the exercise they want to practice by simply performing it. In skeletal feature extraction, Kinect sensor capture both RGB video and depth information, and extract skeletal data in real-time from depth sequences by using Kinect SDK (Software Development Kit). A skeletal image can give the information of human body as depth maps. In the process of activity, parts of human body are in constantly changing state. Therefore the selection of benchmark coordinate system is crucial part for feature extraction. If we select the first frame with movement as the standard skeleton, and use its coordinates, then transform all the other motion skeletons sequence to it. Skeleton sequences can provide abundant information for activities recognition, such as shape, structure, position and, angles Skeleton sequences can provide abundant data for activities recognition, such as shape, structure, position and, angles.

To be precise, a target exercise is roughly performed by the user and capture by Kinect or 3D sensors, resulting in an activity sequence. The system then takes this sequence as input to search for similar video clips in the motion video database (each element in the database is also a human action video captured by Kinect) and returns a ranked list consisting of segmented candidate sequences for the user to select the exact learning exemplar [4].

The second stage is recognition stage. After choosing the exact learning exemplar, the user could follow it with real-time feedback pointing out body joints which are not posed correctly. Based on comparing and analyzing skeleton point correspondences between the save image and the target image in feature matching phase. The system gives the user motion instruction to correct the most inaccurate body joint. Moreover, the system can automatically play back the learning exemplar while the user fails to follow the movements. Flow Chart of the proposed Kinect-based user activity illustrates in Fig. 3. In which skeleton detection of the user in front of the device achieved from the depth image. The skeleton is described by 20 joints as described earlier. Comparison between activity with saved activity occurred. At the end of process result will shown and then saved in database.

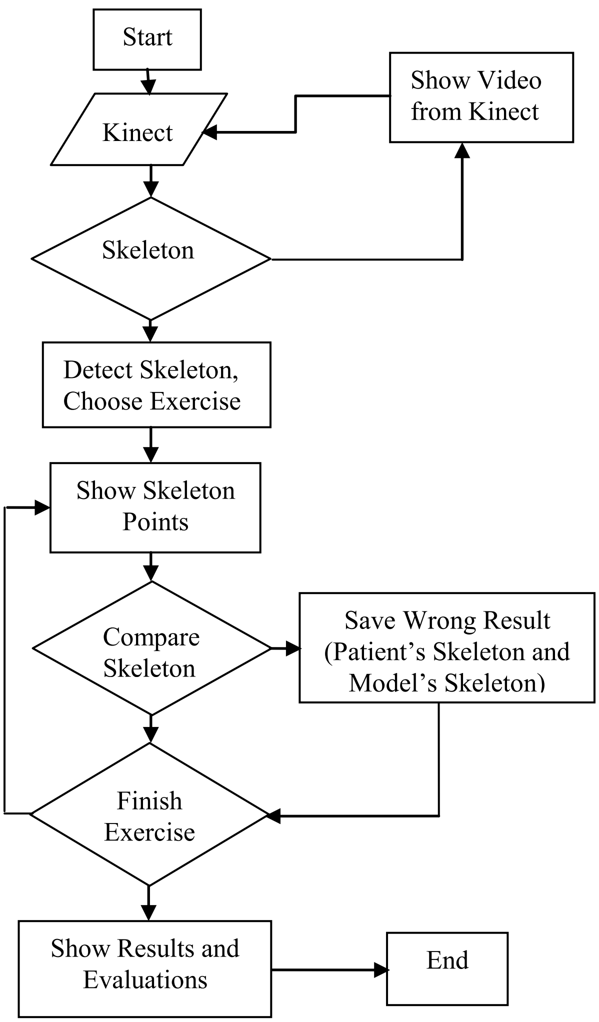

Fig. 3-Flow Chart of the proposed Kinect-based System

V- EXPERIMENTAL SETUP

With Support Vector machine (SVM) we will implement Kinect-based exercise monitoring and guidance system. We developed an algorithm to track the skeleton joints of human body. Support Vector machine (SVM) is a supervised machine learning algorithm which involves predicting and classifying data according to the dataset. Basically SVM are two class classifier which requires labeling of the data and directly applies to the two classes available, but for the actual life problems which requires multiple classes, causes problems and to rectify it Multiclass SVM is used. It forms multiple or two class classifiers based on the feature vector derived from the input features and the class of the data.

In multiclass or multinomial classification, to classify the data we have to create and trained the model. The labeled data set is given to the model and it will give some predictions based upon unseen examples or unseen tupels. Based upon algorithm it classifies the data and give as an output. It collects activity dataset in the form of video's by kinect sensor, as a sequence of some action. After collecting activity dataset feature are extracted in the form of skeleton metrics. It can extract the feature based on different dataset of activity.

Suppose our data set has 'n' classes then according to that we have to prepare 'n' binary classifiers. Basically the rule for one versus all classification technique is N class=N model. As we work with 4 modes, we will learn 4 SVM classifiers. In order to use SVM, we require to extracting certain features from activity videos and corresponding feature vectors corresponding to every activity video in our dataset. We could use the position of selected skeleton joints in every activity as features.

With SVM classification technique to train the system for first training will generate model say M1, second is M2, third is M3, and fourth is M4. The change in position of selected joints and body parts during the activity has been utilized to construct feature vectors for each activity. Each feature vector is the label of the activity involved SVM based training program. Once we constructed the feature vector then, with SVM to classify the activities. To provide data for SVM the feature data set needs to be split into training and testing. According to highest classification probability and class level, data will assign to that class. Table 1. Shows the summary of the joints tracked in human body and their reference points. We use four exercises with SVM multiclass classifier has been used to recognize and classify the activities being performed.

Table 1-The summary of the joints and reference during exercise.

Exercises	Joints tracked	Reference
Hands Sideway	left shoulder right shoulder head	Human skeleton
Raising hands upward	left hand right hand head	Human skeleton
Reaching lateral side stretch	right shoulder left shoulder head	Human skeleton
Knee lifts	right knee left knee left hand	Human skeleton

VI- CONCLUSION

In this paper, we described design and development of Kinect-based physical rehabilitation for exercise monitoring and guidance system with machine learning algorithm. Experimental result shows the algorithm is able to successfully classify and recognize the set of activities The result of our system is shown in fig. 4. This picture shows the user move her hand upwards direction. The system allows tracking body movements during exercise and calculating the position of body joints.

Fig. 4-The user perform activity with hand exercise

The system operated in two stages that is acquisition and recognition stage. The system used both by physiotherapist and patient. By using a program physiotherapist record the exercises the patient should perform. When patient used system he performed exercise and the correct result saved in database. With SVM classification technique, predicting and classifying the activity or exercise which is used by user. Furthermore, for developing rehabilitation exercise system is designed by motion capture, human activity recognition and standard exercises prototype with Kinect device.

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