DIGITAL HUMAN MODEL AND MOTION CAPTURE TECHNIQUES FOR HOME KINESITHERAPY

Karolina Grzechnik and Tadeusz Burczynski

Cracow University of Technology
Warszawska 24
31-155, Krakow, Poland

kgrzechnik@pk.edu.pl, tburczyn@pk.edu.pl

Abstract. The key feature of home kinesitherapy is real-time monitoring of movements and reacting to a wrong behavior. That is why the very important technology challenge is to apply a proper effective and efficient motion capture technique. A system dedicated for such a therapy should be based on a digital human model and involve motion capture techniques. First attempts for such systems have already appeared, but they are not satisfactory for home independent kinesitherapy. This paper presents the definition of the system for home kinesitherapy. It points out the deficiencies of existing systems for completing a full therapy program. Authors describe research results regarding the usage of some motion capture techniques for home kinesitherapy: the advanced and expensive ShapeWrap II system and the cheap Microsoft Kinect Sensor.

Keywords: motion capture, kinesitherapy, digital human model, rehabilitation, Microsoft Kinect

1 Introduction and background

Kinesitherapy is a part of physical therapy - one of the most important aspects of medical rehabilitation. It consists in the movement of the whole body or its parts, in order to achieve recovery of the damaged function of locomotion. Kinesitherapy is divided into passive and active exercises. The latter include: active exercises without assistance, active exercises with assistance and active exercises with resistance [1].

The high cost of kinesitherapy with constant participation of a therapist was a factor that initiated the search for solution for conducting a therapy at patient's home without the presence of a specialist. This treatment may be based only on active exercises that are performed by the patient alone at a specified speed and rhythm. Furthermore, in many cases the therapy in the home environment has positive influence on the patient's psyche and gives better and faster results than treatment at a specialist center. Out of numerous publications about motion capture systems for home rehabilitation ([2]-[8]), those that are most closely related to the work presented in this paper are described below.

In [5], authors propose a home therapy system which recognizes and corrects the performance of patient's movements. This approach allows for rehabilitation without the presence of a physiotherapist. This system is based on skeleton tracking by Microsoft Kinect to capture movements. The demonstrated system recognizes the shoulder abduction movement. During rehabilitation, a patient gets feedback from the system – a positive or negative message on the screen. The experiment shows that an interactive system using Kinect can optimize the treatment.

In [6], the author presents a system that supports physical therapy for students with muscle atrophy and cerebral palsy. The system uses Microsoft Kinect Sensor with an integrated database, video instructions and voice reminders. Kinect recognizes locations of student's joints and uses the data to check if the performed movements are compatible with a standard. The participants repeat movements after video instructions. A therapist can adapt exercises to the capabilities of an individual student and can monitor their progress. The system has interactive interface, which enhances student's motivation to participate in the rehabilitation program.

Authors in [7] demonstrate a comparison between two motion capture systems: the low-cost Microsoft Kinect and high-cost multi-camera OptiTrack. Their experiment was performed on two patients: one male with spinal cord injuries and one healthy female. Each participant performed six exercises compatible with therapist's instructions. Every motion was recorded by both motion capture systems. Authors compared the registered trajectory and timing performance. They presented a simple game-based rehabilitation application. The experiment's results show that Kinect can achieve similar motion tracking performance as the high-cost system and is a likely Virtual Reality rehabilitation device for use in the home environment.

In [8], the authors present two systems for home rehabilitation that were designed as games integrated with Microsoft Kinect. These systems are intended for the elderly to help them in their daily life. The Kinect Sensor is used to animate avatars in the games. During the game, a participant performs simple tasks and scores points, which increases their motivation for rehabilitation. The authors focus on the game design, which is fundamental to create the game that will be useful for rehabilitation in the home environment.

The analysis of existing systems supporting home kinesitherapy allows for the indication of missing features of an ideal system.

2 Definition of home kinesitherapy system

The idea is to create a system for supporting and monitoring home kinesitherapy. The application will simulate human body and its movement by a digital human model. This system will include base moves which can be chosen by a specialist for a particular patient to train at home. Moreover, it will be possible to add new movements prepared individually during medical examinations for some patients. Each patient will have their private account for storing doctor's recommendations. The application will be based on the Motion Capture technique for capturing patient's movements. The Microsoft Kinect will be used for this, so patient must have a computer with the described application and Microsoft Kinect to train at home without a specialist. However, it will be a controlled therapy. Patients will have to repeat each exercise after a digital model from the application. The system will compare their movements and save the results. Application will assist the patient during their training by giving tips. The doctor will have access to the patient's account for monitoring their kinesitherapy. The key parts of the system are gesture visualization, data visualization, transmission and storage of data. The most important issue is to prepare an algorithm for analysis of deviation from the standard in the context of a range, smoothness and duration of motion, pointing errors and monitoring progress by a specialist. The new features which differentiate our approach from other systems are: high precision in controlled home kinesitherapy, possibility to add specific movements prepared individually for a patient, and researching smoothness of motion, giving the possibility to conduct a multi-patient therapy. Furthermore, a very important feature of this system is the option to prepare the scenario of therapy by a doctor who will choose exercises and the number of repetitions. Moreover, the specialist will be able to modify the therapy in any time.

The first step towards new home kinesitherapy system is to check if using low cost Kinect system is sufficient to support kinesitherapy. Another step is to choose and prepare a database of motions which will be used by the system later on.

3 Motion Capture systems

Motion Capture is a technique for acquiring 3D human movements and storing them in a computer system. The stored data can be analyzed and processed later on. Such a technique is applied for modeling human movement in the most realistic and natural manner, transferring real moves to a digital human model. Motion capture is a technique, on which a home kinesitherapy system could be based. A patient would practice repeating after computer human model which would perform movements stored before based on motion capture techniques.

There are a few types of Motion Capture systems which differ mainly in the level of accuracy and price. It is impossible to use the most accurate systems based on markers and cameras for home rehabilitation because of their high cost, occupied area and necessary staff that should be involved. The goal is to use a system that is cheap, easy to use and doesn't occupy too much area. That is why Microsoft Kinect was chosen to be compared with more expensive and advanced ShapeWrap II.

ShapeWrap II is one of portable motion capture systems, ideal for use in every kind of place. Wireless capabilities enable working with ShapeWrap II away from the computer that registers motion data. ShapeWrap II conforms to fit people of nearly any size, and no extra suit is required. The System uses ShapeTapes, long fiber-optic sensor arrays that measure bend and twist from their base to their tip. The ShapeWrap II has four ShapeTapes (two arm tapes and two leg tapes), three Orientation Sensors (Pelvic Orientation Sensor, Thoracic Orientation Sensor, Head Orientation Sensor), and a pair of Foot sensors. The ShapeTapes use their bend and twist data to calculate the position and orientation of a key sensor along the Tape. Orientation Sensors on the pelvis, torso and head all have tri-axial accelerometers, magnetometers and angular rate sensors that measure static and dynamic orientation. Foot Sensors help the software decide when a foot is touching the ground. Each Foot Harness is equipped with the Foot Sensors. The software that accompanies the ShapeWrap II system is called ShapeRecorder. This software displays, captures, and exports motion capture data. It can also be used for viewing and saving data for individual ShapeTapes. The serial outputs are collected by ShapeWrap II's onboard computer. This onboard computer is the Data Concentrator that sends all of the data to the host computer running Shape Recorder. The connection can be made using Ethernet either by cable or wireless [9].

The Microsoft Kinect Sensor was initially designed for an Xbox 360 console that let for interactive environment without any additional controller, but across a natural user interface using spoken commands and gestures. The device has two cameras, infrared emitter, four microphones, accelerometer, and automatic tilt controller. The RGB camera with a 640x640 resolution is used for video image processing. The infrared emitter emits a beam of infrared rays that, having bounced from the surface, are distorted and read by the depth camera. Next the depth camera creates a 3D model of a room and objects in the room. Information about the distance from Kinect to an object gives the opportunity to read a human silhouette and gestures. The available Kinect SDK provides access to capabilities of Kinect's Sensor by tools and library that let programmers create code which responds to an event captured from the outer world. Kinect Sensor and Kinect SDK allow for interactions between the application and the environment according to the scheme below (Fig. 1):

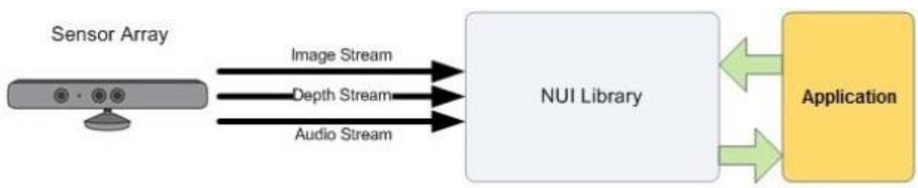

Fig. 1. Cooperation between Kinect Sensor and application [10]

The Natural User Interface (NUI) is the interface between user and application, which allows for their mutual interaction without the need to use any extra devices. The idea is to enable users to use the application in the way that is natural for a human being. The NUI has implemented the following capabilities: access to Kinect Sensor, access to data from RGB camera and depth camera, availability of the tools for skeletal tracking. NUI Skeleton API provides information about the location of twenty parts of the body, which allows for defining their coordinates in relation to the Kinect Sensor. These points (joints) create the skeleton form. The joints let programmers recognize the actual human positions and posture. Through Kinect SDK, programmers can designate the coordinates of all the parts of body and respond appropriately to changes of their location [10].

4 Research

The goal of research described in this paper is to compare two motion computer systems, ShapeWrap and Kinect, in order to use them in home kinesitherapy. The other question which we try to answer is if the cheap and easy-to-use Kinect system is sufficient for such purposes, and if there are any conditions which it should fulfill to be useful.

During the experiment, three movements were examined: (1) flexion and extension, (2) shoulder abduction angle = 90 degrees, and (3) hip abduction. All of the movements were recorded by both motion capture systems at the same time (Fig. 2).

Fig. 2. ShapeWrap II, Microsoft Kinect application, ShapeWrap II Recorder

The participant wore ShapeWrap II which registered the performed motions and recorded them by the ShapeWrap Recorder application, attached to the system. Microsoft Kinect was set to the front of the participant. The application prepared before the experiment registered and recorded joints position as motion animation of the participant. In order to compare the movements recorded by both systems, the digital human models were created. The registered data were converted to the Skeletal BVH (The Biovision Hierarchy).

The Biovision Hierarchy is a character animation file format. It provides skeletal structure information (Fig. 3) in the header section of the file and motion data in the data section. It is important that in the BVH format each joint's position is registered as the x, y, z offset against its parent [11].

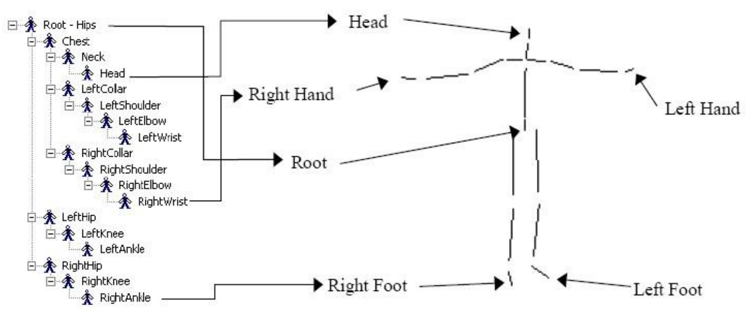

Fig. 3. BVH Skeletal Structure [11]

The data collected by both systems were processed and analyzed in a toolbox for Matlab Motion Capture Toolbox. The data for analyzed movements were scaled and standardized in order to enable comparison between the systems. It refers to appropriate displacements within the space and different numbers of frames in the analyzed systems. The figures below (Fig.4) display trajectories of wrist joint during shoulder abduction movement recorded by both systems.

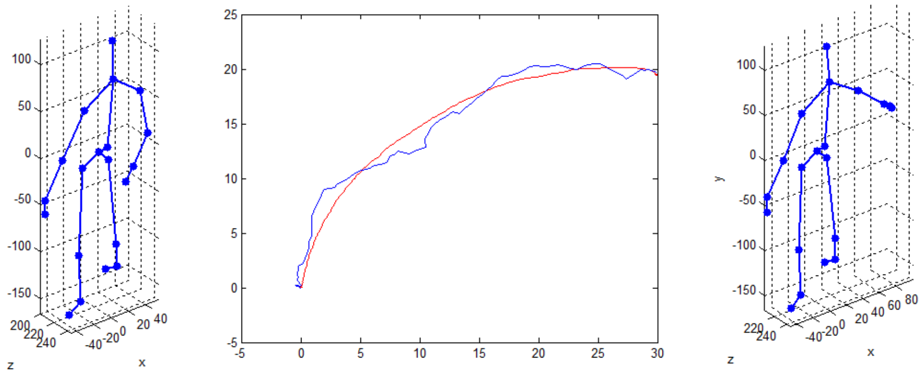

Fig. 4. The Digital Human Models before (left) and after (right) the movement and trajectory of movement (middle) registered by two systems (red – ShapeWrap, blue – MS Kinect)

5 Conclusions

The analysis of results for both systems leads to the following conclusions. The movement trajectory obtained by the ShapeWrap system is more precise than in case of Kinect. The differences, however, are so small that one can assume that the Kinect system will be sufficient for home kinesitherapy. In order to make full use of Kinect, it is still necessary to apply additional algorithms that would correct and smooth the received trajectories.

The experiment proved that ShapeWrap II System does not fulfill the basic requirements of the system for support home kinesitherapy. Very complicated process of putting on all the elements and calibrating system is laborious and requires an extra person to help. The system put on a human body is uncomfortable and it will probably be impossible for people with motor disabilities to wear some of its elements. The process of system calibration could be incorrectly performed because it requires an example position with an arm raised straight. ShapeWrap II has elements that must be worn on the back so exercises in recumbent position would be difficult (Fig. 4). The basic criterion that disqualifies ShapeWrap II as a tool for home rehabilitation is lack of possibilities to perform independent therapy.

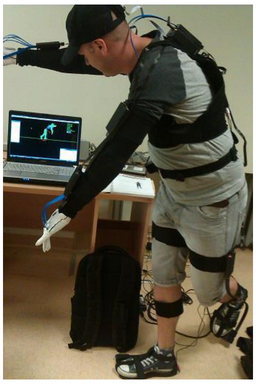

Fig. 5. ShapeWrap II System

The experiment shows that the Microsoft Kinect Sensor meets the requirements of a motion capture system for home kinesitherapy. To use this system, one needs only to connect the device to a computer and enable the adequate application. Microsoft Kinect is very comfortable in use and it allows for performing movements in all the positions. It is suitable for simple motions required in kinesitherapy. Depending on the performed movements, the device must be opposite to the participant or at an angle of 45 degrees. The distance from a patient to the Microsoft Kinect should be about 2-2.5m. That setting of the device provides sufficient accuracy of registered movements.

6 References

1. K. Savić, "Kinesitherapy: one of the most important aspects of medical rehabilitation", Med Pregl. 2005 Nov-Dec;58(11-12):553-7.
2. S. Attygalle, M. Duff, T. Rikakis, He. Jiping , "Low-cost, at-home assessment system with Wii Remote based motion capture," Virtual Rehabilitation, 2008 , vol., no., pp.168,174, 25-27 Aug. 2008

3. H.M. Hondori, M. Khademi, C.V. Lopes, “Monitoring Intake Gestures using Sensor Fusion (Microsoft Kinect Inertial Sensors) for Smart Home Tele-Rehab Setting”, In proceeding of: 1st Annual IEEE Healthcare Innovation Conference of the IEEE EMBS, 2012
4. O. Mirabella et al., „A motion capture system for sport training and rehabilitation”, in Human System Interactions (HSI), 2011 4th International Conference on, 2011, pp. 52-59.
5. Da Gama A. et al., “Improving Motor Rehabilitation Process through a Natural Interaction Based System Using Kinect Sensor”, in 3D User Interfaces (3DUI), 2012 IEEE Symposium on, 2012, pp. 145-146.
6. Jun-Da Huang, “Kinerehab: A Kinect-based System for Physical Rehabilitation A Pilot Study for Young Adults with Motor Disabilities”, Research in Developmental Disabilities, 2011, pp. 319-320.
7. Chien-Yen Chang et al., “Towards Pervasive Physical Rehabilitation Using Microsoft Kinect”, in 6th International Conference on Pervasive Computing Technologies for Healthcare, 2012
8. Borghese, N.A.; Pirovano, M.; Mainetti, R.; Lanzi, P.-L., "An integrated low-cost system for at-home rehabilitation," Virtual Systems and Multimedia (VSMM), 2012 18th International Conference on , vol., no., pp.553,556, 2-5 Sept. 2012
9. “Shape Wrap II”, User guide, 2007
10. “Kinect for Windows SDK”, http://msdn.microsoft.com/en-us/library/hh855347.aspx
11. M. Meredith, S. Maddock, “Motion Capture File Formats Explained”, Department of Computer Science, University of Sheffield