Schreier G, Hayn D, Ammenwerth E, editors. Tagungsband der eHealth2011. 26.-27.Mai 2011; Wien. OCG; 2011.

VALIDATING THE USE OF GAMING CONSOLE SENSORS FOR TELEMONITORING OF PHYSIOTHERAPY EXERCISES

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Abstract

Attending a physiotherapist can be strenuous for patients with impaired functional movement. We evaluated whether exercises can also be telemonitored. To make this technology affordable, cheap sensors are necessary. Literature suggests the use of gaming console sensors, but no validation of sensor accuracy and a usage for real exercises could be found. With a study with patients we found out, that these sensors can indeed be used under certain restrictions about positioning, fixation and types of exercise. It can be detected remotely whether patients do exercises correctly or not.

Keywords –Telemonitoring, Physiotherapy, Wii, Sensors, Validation

1. Introduction and motivation

Functional movement is an important factor to be healthy. When movement and function are endangered by ageing, injury, diseases or environmental factors, physiotherapy is necessary to maximize the quality of life. About ten percent of the total world's population (roughly 650 million people) has a disability. [12] describes the usual physiotherapy exercises as stretching and lifting exercises. It can be painful, repetitive and boring for sick or injured persons, but patient motivation is the decisive criteria for the outcome of any therapy. Additionally, physiotherapy is a process with a long duration. It is crucial for the effect of the therapy that the exercises are done correctly. Daily or weekly meetings between patients and therapists are necessary to monitor the correctness. To reduce the cost of a therapy but still being able to guarantee the quality of the outcome, remote monitoring would help.

Typically, special high-accuracy sensors to measure acceleration and orientation in 3D-space have a high impact on the total price of any telemonitoring system. Alternatively in recent years, gaming consoles also make use of these types of sensors, to detect the motion of players to control games. Nintendo's Wii console was the first available, later followed by Sony's Motion Controller for their Playstation and recently Microsoft with its "Kinect" controller for the XBOX 360 gaming console. The use of acceleration sensors and gyroscopes in commodity goods dramatically reduces the prices. Soon after its release, the Wii remote was reported within a medical background, mostly because playing video games with motion controllers motivate people of every age to move (again). In this context e.g. [4] wrote, that Nintendo's Wii motivates people by making the hard work of

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physical therapy into child's play. The games are very attractive and enjoyable so that patients forget sometimes that they are in treatment and doing physical therapy. Another benefit of Wii sensors is that it is low cost and easy to use, as experienced by the Oxford University team [11].

So far, only ready-made games that have not explicitly been made for medical purposes are used in the literature, like e.g. “Wii Fit” (a general purpose fitness training software that also incorporates some exercises the are at least reasonable for physiotherapy) or “Wii Sports”. Other projects focus on the motivational factor of video games (see next section). We wondered whether game controllers exhibit the necessary accuracy to even monitor the exactness of exercises being done. This has not been tested in any work we have read about so far. Hence, in this project we tested the following hypotheses: (i) Nintendo's Wii sensors (remote and motion plus) can be used as sensors in different physiotherapeutical exercises, (ii) with the sensor's data a computer is able to determine if the exercise is done correctly and (iii) the sensor's data can be used to give feedback about the undergoing exercise. This article can also be seen as a short review about the reported usage of Nintendo’s Wii gaming console for medical rehabilitation.

2. Related literature

In a case report [3], it is shown that the use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy is feasible. The 13-year-old patient was selected for several reasons, including having adequate functional hand skill to manage the Wii remotes, gross motor skills to work in either a sitting or standing position, and sufficient cognitive skills to follow directions, stay on task, and understand the games. There were positive outcomes at the impairment and functional levels. Postural control, visual-perceptual processing, and functional mobility were improved after training. Old age, isolation, disability, lack of mobility and chronic illnesses are the usual problems among older persons and these can be improved by exercise. Social connection, such as having an exercise partner or familial support is one of the barriers particularly to older women to do exercises. The Wii games are relatively easy to play and are designed to be fun and social. 0 made a study using the Nintendo Wii gaming system in healthcare of older women. The study has shown that the participants get benefits such as psychological well-being, getting opportunities to interact with other people and also within their own families. The Wii intervention was empowering and made it possible playing sports sitting down.

In [13] two Lancashire hospitals (NHS foundation trust, UK) are using the Wii to aid the rehabilitation of young patients. The Wii promotes health and fitness through active games. The Wii Fit stimulates interest while performing uncomfortable exercises. The Wii game is being used in an increasing number of NHS physiotherapy departments. [7] also wrote about using Wii Fit for physiotherapy in a UK Hospital. The Wii Fit has been using in the Seacroft Hospital in Leeds England for the patients with prosthetic limb. The Wii Fit helps patients to experience their centre of gravity visually, which is more accurate than their trainer's opinion on their progress. This way, patients learn to stay in balance. A further clinical report by [10] shows that Nintendo Wii Fit could improve dynamic balance control in an elderly patient with balance impairments. It also stimulates the patient's desire to participate in the balance rehabilitation program. The selected outcome measures (Berg Balance Scale, Activities-specific Balance Confidence Scale, Timed Up and Go, and gait speed) were recorded. Comparing pre- and post-intervention, improvements of patients using Wii Fit are seen in all of the selected balance outcome measures.

Several new paper articles [6, 12] report about use of Wii games for rehab therapy by physicians. The movements during playing Wii games are similar to traditional therapy exercises. The patients become so absorbed mentally and they are almost unconscious of the unpleasantness of therapy exercise. The Wii system creates inner competitiveness. Patients want to beat their opponent. Therefore patients forget the boring physical therapy exercises and they do much better with the Wii games. Many people recovering from strokes, heart attacks, sports injuries and car crashes need physical therapy. Often, they have to relearn simple, rote tasks, e.g. walking or feeding oneself. These skills are impossible to get back without motivation. The reported hospitals used the therapy for patients aged from 7 to 75, with issues ranging from knee replacements, spinal cord and brain injuries, to stroke, cerebral palsy and Alzheimer's. The Wii game shows more effectiveness than normal physiotherapy exercises, when the patient must continue rehab on his own after discharge.

In the same year [11] experimented with the accelerometer of the Wii remote for gesture recognition without the gaming console. Wii remote was chosen because of the hardware price, the design and its usability. The team's technique provides a gesture recognition rate between 85 and 95 percent, depending on the kind of gesture. The Wii game is also a new frontier for occupational therapy. Its modified versions can be used to create VR-like therapy systems. The Wii becomes an exciting new therapy device with the low cost, intuitive nature and with benefits paralleling those of virtual rehabilitation [5]0.

3. Methods and experimental setup

The components used during the experiments within this project are a computer, a Java application and Wii sensors. An Asus Eee PC 1000HG is used during the survey to collect data. The application itself is written in Java and uses the WiiRemoteJ 1.7 beta1 library. With this library, the Java application can connect to the Wii remote on Linux and Windows in 32 bit environments. The Wii remote isn’t 100 percent compliant with the HID Bluetooth standard, but it can connect to many Bluetooth-capable computers with some special Bluetooth stacks. For the connection between the Wii remote and the host PC, we used the BlueCove2 library in version 2.1.1. The Wii remote contains a 3-axis accelerometer, a high-resolution high-speed IR camera, a speaker, a vibration motor, and wireless Bluetooth connectivity. The 3-axis linear accelerometer provides the Wii remote's motion-sensing capability and has a ±3 g sensitivity range. The Wii remote can be quite easily connected to a personal computer [8]. The original Wii remote's accelerometer is capable of measuring movement velocity along the X, Y, and Z axes, but only linear acceleration without rotation. According to [2] the problem is that acceleration due to gravity can easily be confused with linear motion when using the device. And though the accelerometer can track gravity, it can't measure horizontal rotation. Gyroscopes, on the other hand, measure rotation directly. These sensors are very responsive and don't amplify hand jitter, but cannot respond to the linear movement that accelerometers specialize in. When a gyroscope and an accelerometer are combined, though, the pair of sensors affords the ability for highly accurate representation of the control device in 3D space. The Wii Motion Plus is a small expansion which we attached to the Wii remote for this research work. It contains two gyro sensors: a dual-axis (pitch and roll) and a single axis gyro (yaw). These two together enables the Wii motion plus to report the angular rate in all three axis, thus allowing full orientation tracking. Our application creates XML files, where the values of the accelerometers and gyroscopes are stored with the time of occurrence. For further analysis, we imported the data to Microsoft Excel (only for a first rough estimation of accuracy).

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1 The library is publicly available at http://www.world-of-cha0s.hostrocket.com/WiiRemoteJ/
2 The Bluecove library is available at http://bluecove.org/

15 test persons were chosen including two children of age 11 and 9, one person of age 17, four persons between 20 and 25, four persons between 35 and 45, two persons between 55 and 60, and two persons between 60 and 70. Among them, 4 persons are hobby athletes, 4 persons have a limitation of movement. Thus, not all persons were able to participate in all exercises. Furthermore, we sometimes experienced a loss of connection and unreliability of the provided data discussed later. The data analysed for each exercise are from at least ten persons. We chose exercises related to real physical therapy from [1]. The exercises were selected by therapists according to the importance of usage in their daily routine. The person is also instructed and demonstrated how to do the exercise. Throughout the filmed execution of the exercises, data is collected from the accelerometers and gyroscopes.

4. Results

In this section the exercises and the positioning of the Wii sensors (Wii remote together with the motion plus), are described. Seven strength and build-up training exercises were chosen with the help of a physiotherapist. We used 2 Wii remotes attached to the persons using elastic bands in each exercise, whose positions are defined according to the directions of the movement of exercises and free movement of the body parts. We elaborated the sensor's positions for each exercise separately and exactly defined the positioning of the sensors to be able to repeat the experiments. See *Table 1* for an overview about the positioning of the sensors for each chosen exercise and *Figure 1* for an illustration of the exercise “Abduction of arm laterally with weight”.

Table 1: This table shows the attachment of Wii sensors to the body parts of the participants.
We used the sensors of two Wii remotes for each the 7 exercises that were chosen as representatives for several classes of rehabilitation exercises in physiotherapy.

Exercise	Wii sensor 1	Wii sensor 2
Abduction of arm laterally with weight	Forearm: front at wrist joint	Shoulder blade
Standing on Tip-toes	Lower leg: back at knee joint laterally	Upper arm – front at wrist joint
Radial abduction of wrist joint	Palm: buttons facing outside	Forearm: back at elbow joint
Biceps curl in supination	Forearm: front at wrist joint	Upper arm: front at elbow joint
Flexion of wrist joint in supination	Palm: thumb between B button and battery case	Forearm: back at elbow joint
Rotation of wrist joint in supination	Palm: thumb between B button and battery case	Forearm: back at elbow joint
Lifting weight dorsally	Palm: thumb between B button and battery case	Upper arm: front at elbow joint

The sensors could not be fixed exactly to the body due anatomical structure and physiological movement. But they were sufficiently fixed to guarantee the comparability of data of all participants. All exercises were done by at least ten participants each. During data analysis, one of these exercises (“Standing on tip toe”) was found to be impossible to be sufficiently recognized by the Wii sensors. This is because the correct movement during the exercise is too little in comparison to other uncontrollable body movements.

The measured data provides information how an exercise was done. In combination with the expected movement, the measured data are analysed. A high difference between the measured values of a known correctly carried out exercise and the corresponding values of the current exercise signifies that the current exercise is carried out wrongly. For statistically determining the correctness of the execution of an exercise, the significant measurements are searched for in each of the six exercises. In all exercises but “Standing on tip-toes” it could statistically determined whether the exercise had been carried out correctly or not. This includes whether the correct starting and end position of the extremities had been reached and also whether the speed of the exercise was too slow, too fast or correct. More detailed results, including setup of the exercises, statistical evaluation of the measured data and discussions of the outcomes can be found in 0.

Figure 1: Example exercise "Abduction of arm laterally with weight".
This exercise is done typically in rehabilitation of clavicle fracture, sternoclavicular joint injuries. This figure shows the starting position, position during movement and the end position of the exercise. A water-bottle is carried as weight throughout the exercise. The arm is abducted from vertical to horizontal position. If the end position is above or under the horizontal line, the exercise is done wrongly. Involvement of gross shoulder movement is also observed.

5. Discussion and Outlook

The most problems we experienced during the research project were related to the fixation of the Wii remotes to the patient's extremities. First, the connection at the junction between the Wii remote and the motion plus is sometimes disturbed by pressure on the connector from the tight attachment and the movement during the exercise. It causes a loss of gyroscope's data for seconds. Using the Wii Remote Plus[1] can avoid this problem. Second, the attachment can also be improved to enable people in the therapy to use the system alone, without someone attaching the sensors to them. For instance, two small pieces of a Velcro hook and loop tape are first attached to the Wii sensor (using doubled-sided tape). Second the person wears the rubber band with another piece of Velcro, where the sensor should be attached to the body part. So that the sensors can be finally attached to the body easily and the shifting of the sensor, accidental pressing at the power-button during the exercises can also be minimised. To get the significant result of the analysis, the movement should be long and fast enough while using the Wii sensor. Most of the measured data are in accordance with the expected value and with acceptable standard deviation. Whether the exercise is done correctly or wrongly can be seen from these data. Moreover, as experienced by other publications about the usage of the Wii in healthcare, people are motivated to do the exercise repeatedly, although they would consider the exercise itself boring or strenuous. Other reviewed publications also describe the positive outcomes using the Wii sensors in healthcare. Also the price of the Wii sensors and its usability are the reasons, why the Wii sensors can be used in healthcare.

There is already some software used by physiotherapists e.g. Wii Sport, Wii Fit. However, the players obtain only rough feedback on his or her exercise. More exact evaluation of the execution of the exercises can be achieved by implementing the methods discussed in this thesis. This enhanced feedback improves the outcome of the exercises, due to exact execution. The next steps include visualization of the movements of patients (e.g. with a simple skeletal model or an avatar), suitable music and getting scores for doing correct exercise, which will also motivate the patients to do the exercises. The physiotherapist can choose and select the exercises by a mouse click for each

1 The Wii Remote Plus controller is an enhanced version of the Wii Remote that already has a built in Wii Motion Plus.

patient and the process of the therapy will be easier. At the same time the progress of the patient can be shown remotely according to the advice of physiotherapists.

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