Process and feedback oriented platform for home-based rehabilitation based on depth sensor technology

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ABSTRACT

In this paper a game-based rehabilitation platform for home usage, supporting stroke and COPD rehabilitation is presented. The main goal is to make rehabilitation more enjoyable and easily accessible for the patients. The platform provides facilities for creation of individualized plans for each patient with a program of game-exercises planned by the patient's caregiver through a web-based planning service. The games are based on specific motion patterns designed in collaboration with rehabilitation specialists. Motion regulations and guidance functions are implemented specifically for each exercise to provide feedback to the user and to ensure proper execution of the desired motion pattern. The caregiver can follow the progression of the rehabilitation and interact with the patient by video conferencing through the web-based service.

1. INTRODUCTION

Following a chronic disease, the primary goal of rehabilitation is to promote a maximal level of function recovery while pushing the bounds of physical, cognitive and emotional impairments (Lange et al, 2011). It is the foundation to enable reintegration into the community and pursued occupation. It has been demonstrated that individuals who perform and have access to multidisciplinary rehabilitation programs show faster functional gains on measures of functional independence and have shorter hospital stays (Hellweg & Johannes, 2008). However, performing therapy exercises without encouragement can cause patients to lose motivation, whereupon the daily process of rehabilitation becomes frustrating and less efficient. Due to increasing medical costs and an increased number of chronic disease patients, every patient's daily exercises cannot be supervised and guided by specialists at all times. Thus, these patients are in need of a functional and reliable home-based rehabilitation system, which can provide cost-effective guidance and encouragement, while supporting remote visual assessment of the performed tasks.

Video games are associated with fun and by developing rehabilitation tools as games the users will perceive motivation associated with playing the games. Although video games have the potential to be used as efficient motivators for performing physical activity, there is a limitation of published research regarding the effectiveness and feasibility of utilizing the motion sensing capabilities of available commercial gaming systems for rehabilitation (Gargin & Pizzi, 2010; Deutsch et al, 2009; Nitz et al, 2010). According to initial case studies, commercial video games can be useful for balance rehabilitation among stroke patients. However, not all commercially available video games are suitable for exercises required for therapy (Nitz et al, 2010; Lange et al, 2010). Furthermore, by extending the gaming platform with video-conferencing and web-based planning and follow-up systems, the rehabilitation can be performed in the patient's home while the physicians, physiotherapists and other related medical staff can monitor and follow up the progression from a distance. Accurate and proper tracking and feedback of motion performance is important in order to achieve maximum effect of the rehabilitation.

In this paper, a work in progress Kinect sensor based platform for home based rehabilitation of COPD and stroke patients is presented. Specific stroke and COPD rehabilitation exercises with different fields of applications are incorporated into the developed games on the platform.

2. MATERIAL AND METHODS

The elaborated home based rehabilitation platform consists of a Kinect 2.0 sensor, a computer with software and a display. The reason for this setup is that the equipment could be easily presented to the user. Provided the user already has a TV screen and a computer, the software and the Kinect sensor can be delivered to the user in a reasonably small box at an affordable cost. Each patient's respective caregiver has access to a web-based system where they can design and plan a rehabilitation program adapted to the specific conditions and needs of the patient. The rehabilitation gaming platform downloads the planned exercises from a server, which enables the user to perform game-based rehabilitation exercises at home, with exercises that are tailored for the individual patient's therapy goals. Motion data from the sensor is collected for each game session and used for motion assessment. The data is also used to provide guidelines and feedback for the user to learn the correct execution of the exercises.

The system displays live video from the Kinect camera on the screen. The user sits or stands up (depending on the exercise) at an appropriate distance from the sensor so that the entire body is visible on the screen. In the game mode, 2D images are placed on the screen in order to activate the user, see figure 1. The user's task is to interact with the objects using different body parts. The placement of the images and the target joints in question determine the type of exercise. Each game is based on a specific pattern of motions designed in collaboration with rehabilitation specialists for COPD and stroke. The games have 10 different levels of difficulty adjusted to the particular exercise in question. There is also a high score list of all the played levels in each game.

Figure 1. *User participating in a boxing game*.

In order to assess if the user performs the exercise correctly, the entire exercise execution is first divided into sub-parts and a start and stop position is defined. Orientation and guideline controls specific for each exercise, with consideration to the defined steps and points, were then implemented in the code to ensure the correct execution. Some of the controls inhibit the progression of the game until the proper motion has been achieved. Other controls provide user guidance through text and voice instructions when the functions are triggered by specific movements.

3. PLATFORM ARCHITECTURE

The rehabilitation platform consists of three systems with integrated components: the caregiver's planning and follow-up system, the patient's gaming system and the web/server system.

1. The planning and follow-up system is a server system accessed through a web-based front-end. Each caregiver (physician, physiotherapist or other related medical staff) has a user account on the system with access to planning tools and progression reports on the associated patients accounts. The system enables the caregiver to design rehabilitation programs for the patients, based on the developed Kinect exercises that can be adjusted for each individual patient's needs and condition. An integrated audiovisual communication system enables the caregiver to interact with the patient through live video and audio. The

caregiver can see what the patient sees on the screen and interact with the patient while performing different tasks in the game.

2. The patient's gaming system is a stand-alone software application running on a computer in the patient's home. The entire game (including menus and settings) is controlled by hand gestures recognized by the Kinect sensor, which avoids the need for additional control devices. The game has two settings, one patient setting and one guest setting. The patient setting is accessed with the username and password of the patient account registered on the server system. When logged in as a patient, the only accessible exercises are those exercises that are planned for the day by the caregiver. The patient setting thus requires Internet access to maintain its connection to the server and to support video-mediated communication with a caregiver. A guest user can access all developed exercises from a menu and adjust the level by choice. Guest users' exercises are not registered.
3. The server system operates as a memory storage of patient specific information that can be transmitted between the patient and the caregiver system. The server stores patient information, such as planned exercises, results of performed exercises uploaded to the server and corresponding assessment data. Once the caregiver has planned an exercise, the information about the daily planned exercises can be obtained by the patient's gaming platform. After execution of the planned exercises, the results are sent back to the server. The high score information of each exercise is however stored locally on the computer hard drive for each specific user.

There are currently 16 developed exercises with different moving patterns and different goal-oriented rehabilitation targets. Each game has 5 levels of difficulty with settings particularly adjusted to the exercises and estimation of patient's capabilities in different conditions. Regulations and control functions have been designed and implemented particularly for each game. These are regulated to prevent cheating, correct movement patterns and for providing guidance to the user. In addition to the rehabilitation exercises, three different assessment tests have been incorporated for COPD patients. Two of the assessment tests are commonly employed questionnaires used for assessment of the current state of the disease in clinical facilities. The third one is specifically implemented for this application as an assessment of the patient's leg muscle strength.

An example of an implemented game is the picking apples exercise. The aim of the game is to pick as many apples as quickly as possible. The apples are placed at a horizontal distance from the shoulders. The apples positioned on the right side are picked with the left hand and apples placed on the left side are picked with the right hand. Text and vocal guidance is provided if the user reaches for the apples with the wrong hand. Guidance is also provided if the user reaches slightly forward to pick the apples instead of reaching directly to the side and the game awaits the user to correct the motion before the apple is removed. Between each picked apple, both hands must be brought back to the center of the body before the next apple appears as a cheating precaution. The distance of the apples position from the shoulders and the number of repetitions increases with the levels and the time frame the user has to pick the apples decreases with the levels. In this exercise the user practice mobility training in shoulder joints and stability training for torso/back. If the subject is standing up while performing the higher levels, the exercise also provides leg strength or balance dependent on the feet distance separation. At the end of the session the fastest picking speed, the average speed and the number of taken apples are presented on the screen.

The games are performed while sitting or standing up depending on the user's physical capabilities and condition. Hence, the difficulty of the games can also be adjusted by alternating the user's performance positions. The simplest case is when the user sits on a chair with the back leaned against the backboard for full support. Next step to increase the difficulty is to sit on a chair with no backboard, and then standing up as a final step. To aid the balance in the standing position a chair or likewise object can be used as support to reduce the risk of falling. To increase the load further, the subject can use elastic rubber bands or hold dumbbells or likewise options in the hands while performing the exercises.

Maintaining a correct posture is important in the execution of several of the developed exercises to obtain full benefit. Position data of the head, neck, shoulders and mid spine was collected from a number of test subjects to observe detection parameters of three types of improper postures: 1) when the posture is hunched forward, 2) when the shoulders are tensed and raised upwards and 3) when the subject is hunched backwards. By utilizing height distance ratios between the tracked joints, threshold values for standing users with tensed shoulders have been found. However, in sitting position the same controls proved unreliable. The horizontal distance between the head and hips/mid spine can be used to indicate hunched positions. However, to optimize the detection of hunched positions a calibration position is necessary to collect user specific data.

4. DISCUSSION & CONCLUSIONS

The home-based rehabilitation system functions as a cross organizational cooperation, where the participation of different care and nursing unit actors is required. All actors involved can access selected information, adjusted for the actor's role in relation to the individual, from a distributed unit. The main focus is the patient's general condition, situation and needs. The purpose of the rehabilitation platform is not to replace the overall recommend rehabilitation activities, but to facilitate and enhance the patient's daily physical or cognitive activity.

The platform is in an early development and evaluation phase. Proper evaluation of patient trials is required in order to fully examine the functionality and effectiveness of the gaming platform. Future work is also intended to expand the client's video-mediated communication system further by introducing a patient group chat option. Furthermore, the possibility of including multi-user exercises in the game, which can be performed at the same location or distributed using video-mediated communication, will be explored. The addition of user friendly interactions and conversations is expected to improve user's acceptance of the system.

Our hypothesis is that the game will provide a more entertaining rehabilitation experience, thereby encourage the user to perform the exercises on a regular basis. The information and feedback about the execution of the exercises could also result in improved movement patterns and thus render the rehabilitation more effective.

The game-based home rehabilitation platform provides COPD and stroke patients with a reasonably priced, easily manageable and entertaining rehabilitation system. The developed system offers improved community of care, encouragement to perform rehabilitation on a regular basis and reduces the need for travel. The motion tracking of the sensor combined with guided feedback helps to improve the execution of the exercise motion pattern and thereby induces efficient rehabilitation training. The stored information of the activity and the results enables the user and other involved parties to follow up on the progression of the rehabilitation. Future work will be done to include communication possibilities not only for health care personnel, but also for friends, relatives and other patients.

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5. REFERENCES

Deutsch, J. E., Robbins, D., Morrison, J., & Bowlby, P. G. (2009). Wii-based compared to standard of care balance and mobility rehabilitation for two individuals post-stroke. In *Virtual Rehabilitation International Conference, 2009*, pp. 117-120.

Gargin, O. T. R., & Pizzi, O. T. R. (2010). Wii-HAB: Using the Wii video game system as an occupational therapy intervention with patients in the hospital setting. *Population Health Matters (Formerly Health Policy Newsletter)*, *23*(1), pp. 4.

Hellweg, S., & Johannes, S. (2008). Physiotherapy after traumatic brain injury: a systematic review of the literature. *Brain Injury*, *22*(5), pp. 365-373.

Lange, B., Chang, C. Y., Suma, E., Newman, B., Rizzo, A. S., & Bolas, M. (2011). Development and evaluation of low cost game-based balance rehabilitation tool using the Microsoft Kinect sensor. In *Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE*, pp. 1831-1834.

Lange, B., Flynn, S., Chang, C. Y., Ahmed, A., Geng, Y., Utsav, K., & Rizzo, A. (2010). Development of an interactive rehabilitation game using the Nintendo® WiiFit™ Balance Board for people with neurological injury. *Topics in Stroke Rehabilitation*, *15*(5), pp. 345-352.

Nitz, J. C., Kuys, S., Isles, R., & Fu, S. (2010). Is the Wii Fit™ a new-generation tool for improving balance, health and well-being? A pilot study.*Climacteric*, *13*(5), PP. 487-491.