Physiotherapy for Elderly through Exergames using Microsoft Kinect Sensor

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Abstract:
Falls in the elderly is a big issue and thus physiotherapy through daily exercise is essential to strengthen the dedicated muscles. However, exercise in elderly always relates to low adherence and unexciting. In this paper, we propose a simple form of exercise through video games that might attract the attention of the elderly. The entertainment based exercise or exergame which is a combination of exercise and video game is developed for the targeted elderly group in order to prevent their sedentary lifestyle. The developed exergame is focusing on arms and legs dedicated games. The arms game targets on improving the stability by lowering down the center of gravity with the help of expanding the arms apart to achieve a better balancing, while the legs game targets on the training of the leg muscles that stronger leg muscles means the elderly falling probability would be less. The choice step reaction time (CSRT) measurements during the games will be extracted and analyzed. This data can be used as a simple clinical test in assessing the risk of elderly fall.

Keywords: Physiotherapy, exergame, elderly fall, sedentary lifestyle.

1. Introduction
Falls in the elderly are a major problem which may result in rehabilitation and medical intervention [1]. Approximately one in every three elderly or one-third of the elderly aged 65
years and over at least fall once every year [2], [3]. Falls are very common in elderly due to various physical constraints. Falls in the elderly is referred as a sudden free drop or descend to the ground due to loss of body balancing. Decrement in balance is common among elderly and it may increase risk of falls. Balance is one component related to the significant problem of postural instability. It is influenced by various factors such as muscle atrophy, calcification of tendons, and ligaments, as well as the increased curvature of the spine [4]. The decrease in muscle mass which also known as “sarcopenia” has also been demonstrated to be associated with decreased muscle strength among elderly [5]. If postural control is referred as the ability to maintain, achieve, or restore a state of balance during any activity [6], thus, impairment of muscle strength and loss of postural control has been found to be the main factors of susceptibility to falling [7], [8]. Therefore, there is high possibility of institutionalized elderly with wheelchairs due to falls may have sedentary lifestyles in the past.

The term "exergame" which is a joining of words “exercise” and “game”, is defined as a video game with an interface that requires active involvement and physical exertion of a player to perform physical exercises in order to control the game [9]-[12]. The word "exercise" refers to physical activity that may improve physical health through muscular exertion and the word “game” refers to video game activity with rules, goals and feedbacks that performed through the utility of computer game interface consoles or other devices. Hence, the exergame is designed to track body motion, such that the interaction is not only based on hand coordination, but requires full body movement to control the game. This full body motion video game may provide fun which is expected to motivate elderly to keep active in performing physiotherapy programs to stay physically fit and thus increase the mobility of elderly. Since video games are also considered as one of the contributing factors to sedentary lifestyle, the physical activity games, exergames, could be a powerful tool to overcome it.

In this paper, we propose an entertained exergame as a physiotherapy program which might attract the adherence among the elderly. We have developed the arm and leg dedicated games which target on improving the stability through better balancing and the muscle strength mean to reduce the risk of falling among the elderly. These exergames based physiotherapy programs are being developed by using the third party game engine called Unity3D which is compatible with Microsoft Kinect Sensor. The suitability of the developed exergames is based on the needs of elderly and their preferences. The game user interface (GUI) of exergames is designed to be as simple as possible in order to not confuse the elderly when the exergames are played. Moreover, the choice step reaction time (CSRT) measurements are extracted and analyzed during the exergames. The extracted CSRT information comprises of decision time, movement time and a few other parameters. This information can be used as a simple clinical test in assessing the risk of elderly fall. If the movement time of the elderly is higher, it means that the elderly has weak muscles and hence might have a high risk of falling.
2. Microsoft Kinect Sensor

Microsoft Kinect sensor as shown in Fig. 1 is a motion sensing device that can capture human body movement with a camera add-on peripheral. It is primarily developed for Microsoft Xbox 360 video game consoles such that the players can interact with the game through gestures and body movement [13],[14]. The Kinect sensor has attracted the attention of many researchers due to its ability to produce high resolution depth maps in real-time. Kinect provides an easy way to track body skeletal and obtain the information of joints. The Kinect sensor includes an RGB camera, a depth sensor and a multi-array microphone. It provides full body three dimension (3D) motion capture, face and gesture recognition. The depth sensor consists of an infrared laser projector and a monochrome CMOS sensor [15]. As shown in Fig. 1, Kinect sensor is embedded in a horizontal bar to a small base with a motorized pivoting capability designed for repositioning its view to detect users. The cameras from left to right are infrared (IR) projector, RGB camera and IR monochrome camera which are combined together to obtain the 3D image including depth map calculation. Fig. 2 shows the extracted joints and skeletal information from the Kinect sensor.

![Fig. 1. Microsoft Kinect sensor.](image)

![Fig. 2. Joints and skeletal information extracted from Kinect Sensor.](image)
### 3. Development of Physiotherapy Based Exergames

The exergames are developed using Unity3D game engine. The integration of Unity3D with Microsoft SDK achieved with script pre-written by RF-Solutions which can be downloaded from the Unity3D asset store. The title of integrated script is known as ‘Kinect with MS-SDK’ [16]. We develop the dedicated physiotherapy based arm and leg exergames which targeting on improving the stability through better balancing and the muscle strength mean to reduce the risk of falling among the elderly. The overall design and development layout of both exergames are shown in Fig. 3. Initially the Kinect sensor is initialized and being looped until the player is present. The program will then detect the player’s posture and gesture while moving the avatar accordingly. When the player hits certain target, the scoring system will update and finally when the exergame is over, the extra body information will be displayed on the screen.

![Flowchart of exergame development process](image)

**Fig. 3.** The flowchart of exergame development process.

#### 3.1 Arm Exergame

The arm exergame will focus on movement of hands. The objective of this game is to improve the balancing of elderly by stretching out their hands horizontally. This act can lower down the center of gravity and hence improve balance in elderly. The player needs to perform the extra gesture or posture in order to control the game avatar. Hence, the system will be detecting different gesture and posture information and translate the information to move the avatar.

In the arm exergame, the player will be running through obstacles and collecting power ups. There is a timer to show the player about the balance duration left to play the round. The screenshot of this exergame is shown in Fig. 4. To extend the time, the player needs to consume banana, while the alcohol bottle indicates a time deduction. The road block in the game acts as
one of the mechanism to stop the player from continuing the game. To overcome the road block the player must jump over the road block. Bear in mind that the player does not need to perform a jumping gesture as the elderly are not advisable to jump. Instead, the player can perform another gesture to initiate a jump animation in the avatar.

Fig. 5. shows the posture information that can be detected by the system and its corresponding results on the avatar. The player needs to raise the right hand to start the game, while raising the left hand to pause the game. To select and click on certain buttons on the GUI, the player needs to hold the fist. To steer the avatar to the left, the player needs to perform a ‘Fly Left’ posture, while to steer the avatar to the right, the player must perform a ‘Fly Right’ posture.

Fig. 6. shows the flapping gesture recognition in the game. This gesture is actually a consecutive list of gestures performed under a certain time frame. It can be considered as dynamic movement when compared to the posture. The flapping gesture comes from the idea of a bird flapping its wing to increase the altitude. It will be used to initiate a jump animation in the avatar. The system will start detecting the very first jump step posture follow by the second and third jump step postures. If all of the postures are performed under a certain time frame, the jumping gestured is recognized.

![Fig. 4. Screenshots of arm exergame.](image)

![Fig. 5. List of posture recognized by the system.](image)
3.2 Leg Exergame

Physical dance mat has been used for motor rehabilitation purposes. The results shows significant improved in Timed Up and Go test (TUG) - a simple test that uses time required for a person to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down [17]. The same game mechanism will be used in the developed leg exergame. The major difference is the absence of a physical dance mat. Instead, an imaginary dance mat is used. Besides, the player information like the ‘Decision Time’ - time required for a person to react once the new pad pops up is being extracted solely from the camera sensor point of view without any other physical sensor.

The existing dance game in the market aims at younger consumers, but it does not fit the requirement of elderly. Hence the exergame has been slightly modified as shown in Fig. 7. Before the game starts, there is a total of eight large color pads surrounding the avatar and two small color pads below the leg of an avatar. When the game starts, all of the eight large color pads will disappear and for each interval of two seconds one of the eight color pads will pop up. The player then moves the leg and steps on the color pad that shows up. While the two small color pads act as the center point of asking the player to move the leg back to center before going for another large color pad.

Fig. 6. Flapping gesture to perform jump animation.

Fig. 7. Screenshot of Leg Game before the game starts.
4. Choice Step Reaction Time (CSRT)

The CSRT measurement can be used as clinical fall risk assessment test. The developed exergame provides a platform in the leg exergame to detect and measure the CSRT related information such as the followings.

- **Decision Time**: The time once colored pad pops up until the moment the foot is lifted away from the center pad. The decision time is used to see how fast the player can react once the pad shows up. It is believed that elderly with higher decision time is more prone to falling.
- **Movement Time**: The time taken once the foot is lifted away from the center pad until it hit the colored pad that pops up. In this developed exergame, a new policy has been set to only accept condition where the decision time is greater than the movement time. This is due to the energy and time that are being consumed to lift up a static leg should be larger than the required to move the leg towards the colored pad as it is learned from inertia. Thus, this extra measurement will ensure the data taken from the steps information has less error rate.
- **Response Time**: Decision Time + Movement Time. Since the decision time and movement time are presented, both of them will be combined to compute a total time needed to touch the colored pad that is showing up.
- **Step Length**: It is the distance between left and right feet after colored pad is touched. The information from the step length could be used by the clinical assessment test to see how well the elderly can extend their legs. Normally, the elderly with a larger step length would have better functional legs muscles and hence would be less prone to falling.

Besides, there are a total of three timers and one mechanism that corresponds to CSRT information extracted from the exergame as follows.

- **Count Up Timer**: This timer will start counting if two conditions are fulfilled, thus when both feet of player are standing right on the middle pad and the player must present in the exergame. When the timer reaches two seconds, a new pad will be popped up. Whenever one of the player’s foot leaves the middle pad, the timer will pause otherwise no new pad will be popped up. This measurement ensures the player does not cheat in the exergame by not placing their feet back to the original location which is the center of all pads. The Count Up Timer will continue to increase until the one of the player’s foot leaves the center pads. If the player does not move his leg away from the middle pad even after the colored pad shows up, the timer will continue to increase until it reaches 10 seconds. The current colored pad will then disappear while the timer revert back to zero until the next two seconds is reached to show the new pads. Besides, when the player touches the popped up colored pad, the Count Up Timer will change back to zero until the moment where both feet of the player have been moved back to the original position before it restarts again.
- **Decision Timer**: This timer will be started only when the count up timer is larger than two seconds, which randomly pops up one of the colored pads and continue to increase until one of the player’s feet leaves the center pad. Decision Timer will be reverted back to zero when the player touches the colored pad.
• Movement Timer: This timer starts when two conditions are met. First, the countdown timer must be at least two seconds indicates that the colored pad pops up. Second, one of the feet must leave the middle pad. This timer will again be reset once the player touches the popped up colored pad.

• Step Length Mechanism: The step length will be calculated by getting the displacement of the foot once the foot touches the colored pad.

Before registering and recording all the CSRT information stated above, the program will make sure that the colored pad is touched.

Fig. 8 shows the tabulated data of CSRT in the “Game Over” GUI. An average of each element is calculated and tabulated at the last row of the CSRT table. This average value will be used to determine whether the players’ leg muscle is strong enough to move their legs in a set of times. Bear in mind that this CSRT measurement has yet been a standard to assess the player’s risk of falling. Hence, the threshold value for each level of stability is set solely by comparing the capability of the elderly with the young player as normalized value. Moreover, ten data have been randomly taken from different young players for stepping the eight colored pads. The results of average values are being tabulated into Fig. 9.

From this figure, we can see that the average of Decision Time for all three attempts is almost the same. This is due to the same player has played the game three times in a row. It can be said that the produced result is consistent and hence should reflect the accuracy of CSRT measurement. Besides, the Movement Time has an average of 0.18 seconds, which can also be considered as a consistent read. The results also show that the Decision Time is always larger than Movement Time. This is due to the reaction time will be slower as compare to the time required to move their legs towards the colored tiles. If the condition is not met, the current data would be discarded and a new tile will pop up. Furthermore, we can see that Decision Time has larger variation than Movement Time. This is mainly due to the loss of sight in focus will influence the Decision Time. This means the Decision Time is measuring the concentration of players, while the Movement Time is measuring the strength of player’s leg muscles.

![Game Over]

Fig. 8. The CSRT measurement from leg game.
5. Conclusions

This paper concludes with the presenting of two physiotherapy exergames that are designed and developed to help the elderly to exercise while having entertainment. This game is being developed by the game engine called Unity3D which is compatible with Microsoft Kinect Sensor. This exergame is initialized by studying the needs of elderly and their preferences. The developed exergames consist of the arms and legs GUIs. The GUI is made as simple as possible such that the elderly would not be confused when play the exergames. Arm game aims to train the elderly on balancing, while leg game is designed to train the leg muscles of the elderly, such that they will have stronger leg muscles to tackle muscle weakness and hence minimize the risk of falling. This developed exergame can also extract body information such as CSRT measurement. The CSRT information comprises of decision time, movement time and a few other parameters. These parameters will be used as clinical based assessment for the risk of falling in elderly. For instance, if the movement time of the player is higher, it could mean that the player has weak muscles and hence might have a high risk of falling.

References


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