Chapter 3
Dynamic Difficulty Adjustment (DDA) on a Serious Game Used for Hand Rehabilitation

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ABSTRACT

Serious games have been used for assisting people in physical rehabilitation for hands. People might have different degrees of mobility in their hands; consequently, it would be convenient that the game could be adapted according to the range-of-motion in performing hand movements. This study implemented a serious game for hand rehabilitation with two play modes. Mode one does not adjust the game difficulty; whereas mode two adjusts the game difficulty according to the player's range-of-motion in performing flexion, extension, ulnar, and radial deviations. The game difficulty was adjusted using fuzzy logic to compute positions at which the rewards will be displayed at the game scene (easy, medium, and difficult positions to collect the rewards). Four participants played both modes. Two-tailed t-tests revealed that there were no significant differences between both modes in terms of rewards collected ($p = 0.6621$), play time ($p = 0.8178$), and "game engagement questionnaire" score ($p = 0.1383$).

INTRODUCTION

Hands play a key role in daily activities. People use them to interact with the world. Nevertheless, due to accidents or medical conditions, people might lose mobility in their hands; consequently, they might require physical rehabilitation.

According to Walsh et al., (2002), "exercise forms a crucial part of a patient's motor rehabilitation in terms of upper and lower limb function as well as prevention of muscle atrophy" (p. 2).

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The main problem in the traditional rehabilitation method is the lack of motivation in patients; therefore, the performances of the rehabilitation exercises might become frustrated and boring. To cope with this issue, robots have been used to assist people during their motor rehabilitation exercises. For instance, a review on robots employed as assistive technologies for rehabilitation on upper limb can be found in (Narayan et al., 2021). In the same vein, robots have been employed for lower limb motor rehabilitation (Alvarez-Perez et al., 2020; Hussain et al., 2017, Hussain et al., 2021).

On the other hand, researchers (Lohse et al., 2013) have studied that video games can be used as a therapeutic tool in physical rehabilitation due to their motivational and engagement properties (e.g., optimal challenge, rewards and feedback provided to the players). As can be seen, these games are focused on assisting people in their rehabilitation processes. These types of games are called serious games. According to Zyda (2005), a serious game can be defined as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (p. 26).

It is important to remark that serious games have been used to assist therapists in the rehabilitation processes of patients on emotional health aspects (e.g., anxiety and depression (Abd-Alrazaq et al., 2022; Barnes & Prescott, 2018; Dias et al., 2018), autism spectrum disorder (Silva et al., 2021; Tsikinas & Xinogalos, 2019), phobias: acrophobia (Sharmili & Kanagaraj, 2020), spider phobia (Lindner et al., 2020)) and motor rehabilitation (e.g. ankle rehabilitation (Hendrickx et al., 2021, Feng et al., 2018), finger rehabilitation (Rahman, 2017; Aguilar-Lazcano & Rechy-Ramirez, 2020), shoulder rehabilitation (Viglialoro et al., 2020; Steiner et al., 2020)), so that the patients could be engaged to the rehabilitation and therapy. Additionally, virtual reality has been used in serious games for upper limb rehabilitation. For instance, Wang et al., (2022) conducted a review on game-based virtual reality systems for upper limb rehabilitation on people that have suffered a stroke to assess the effectiveness of these systems. As a result, authors found that games based on virtual reality for upper limb rehabilitation are more effective than traditional rehabilitation on people suffering cerebral apoplexy.

In terms of wrist motor rehabilitation, the majority of these games are controlled using rehabilitation exercises for the wrist (e.g., flexion, extension, ulnar and radial deviations, pronation and supination of the wrist). The wrist has two main joints, radiocarpal joint and midcarpal joint, that are involved in these rehabilitation exercises (see Figure 1). The intensities of the movements depend on the range-of-motion (ROM) that the patients might have in their hands. According to the American Physical Therapy Association (2001), the range-of-motion "is the arc of motion that occurs at a joint or a series of joints".

Several studies have been published on using serious games for hand rehabilitation. Some serious games are played using hand movements detected via cameras.

For instance, two games called SpongeBall and SpaceRace were played by using hand movements identified via a webcam and thermal camera (Evett et al., 2011). Computer vision was employed to recognize the hand movements. Specifically, in the SpongeBall game (i.e., a shooting target game), the player moves the hand and selects a ball by pinching on it, then places the ball at the desired position and opens the hand to throw the ball to the target. In the SpaceRace game, a ship is controlled using rotation (pronation and supination of the wrist) and translation hand movements; so that the ship navigates and avoids obstacles displayed at the game scene.

Other studies have used Leap motion controller (i.e., a sensor based on infrared cameras that provides X, Y, Z coordinates of the phalanges, wrist, palm and elbow) to detect hand movements that are employed to play the game.