A HOME-BASED SUPPORT ENVIRONMENT FOR CEREBRAL PALSY TREATMENT

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Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

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ABSTRACT

A HOME-BASED SUPPORT ENVIRONMENT FOR CEREBRAL PALSY TREATMENT

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The physiotherapy conducted for the treatment of children with Cerebral Palsy is a difficult process for the patients, parents and physiotherapists because children may not understand the necessity of the treatment and may be unwilling to exercise because of boredom from repetitive therapy sessions, it requires to allocate time in hospital, it requires home exercises to be more effective, it is costly and requires the physiotherapist's steady control. In literature, there are several studies on the systems that support physiotherapy intended for improving motivation of children. On the other hand, usage of these systems is limited in Turkey, where higher rate of children with cerebral palsy births occur in comparison to most of the developed countries. Furthermore, most of the systems have been developed for hospital use and are unaffordable for low income families. In this study a low-cost system based on virtual reality technology is proposed that provides children with hemiparetic cerebral palsy to exercise in their home without the insistence of their parents and entertainingly. Based on this system, feasibility of similar systems that can be developed is discussed.

Keywords—cerebral palsy; upper extremity; hemiparesis; virtual reality; home exercises; motivation

ÖZ

SEREBRAL PALSİ TEDAVİSİ İÇİN EVDE KURULACAK DÜŞÜK MALİYETLİ DESTEK ORTAMI

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Serebral palsili çocukların tedavisi için yürütülen fizyoterapi, çocuğun tedavinin gerekliliğini idrak edememesi ve tekrar eden terapi seanslarından sıkılması sonucunda egzersizleri yapmakta isteksiz olması, seansların hastanede vakit ayırmayı gerektirmesi, daha etkin bir tedavi için evde egzersiz yapmayı gerektirmesi, maliyetli olması, fizyoterapistin sürekli takibini gerektirmesi gibi sebeplerle hasta, aile ve fizyoterapist için zorluklar taşıyan bir süreçtir. Literatürde egzersizleri bilgisayar ortamında oyunlaştırarak serebral palsili çocukların motivasyonunu artırmaya yönelik, fizyoterapiyi destekleyici sistemler üzerine çok sayıda çalışma yer almaktadır. Buna karşın, gelişmiş ülkelerin birçoğuna kıyasla yüksek oranda serebral palsili çocuk doğumu gerçekleşen Türkiye'de bu sistemlerin kullanımı limitlidir. Dahası, bunların birçoğu hastane kullanımı için geliştirilen ve fakir aileler için yüksek gelebilecek maliyetlerle satın alınabilen sistemlerdir. Bu çalışmada, hemiparetik serebral palsili çocukların ebeveylerinin ısrarını gerektirmeden evde eğlenerek üst ekstremite egzersizi yapmalarını sağlayacak, sanal gerçeklik teknolojisine dayalı, düşük maliyetli bir sistem önerilmekte olup; bu sistem üzerinden yola çıkarak, oluşturulabilecek benzer sistemlerin fizibilitesi ve etkinliği üzerinde tartışılmaktadır.

Anahtar Kelimeler— serebral palsi; üst ekstremite; hemiparezi; sanal gerçeklik; ev egzersizleri; motivasyon

To My Parents

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LIST OF ABBREVIATIONS

CD: Compact Disc

CP: Cerebral Palsy

PC: Personal Computer

RQ: Research Question

Web Cam: Web Camera

CHAPTER 1

INTRODUCTION

In this chapter the problems encountered during the treatment process of cerebral palsy (CP) which derive the motivation of the study are discussed. Additionally, purpose of the study, significance of the study and the limitations are all discussed in the following sections.

1.1 Motivation and Problem Statement

In the literature it is reported that regularity is essential in cerebral palsy treatment to learn motor skills and improve the performance [9]. Studies show that, after performing the required exercises repetitively and regularly, some improvements on motor skills and performance of the patients that receive physiotherapy were measured [6] [7] [14] [25]. Since participating in therapy sessions under the supervision of a physiotherapist is not always possible, home exercise programs are supportive in physiotherapy for creating a regular treatment process. In case of physiotherapy of children, since they may not be awake to the necessity of exercising, they may usually be unwilling to perform repetitive exercises and get bored. Studies show that game-like computer environments specifically developed for the treatment for specific purposes are one of the tools that can motivate children to exercise and support the therapy providing several benefits for physiotherapy [6] [16] [18] [20]. However, most of these systems were developed only for hospitals or treatment centers and are not suitable for exercising at home. Moreover, accessibility to these systems is very limited in Turkey, especially for the centers and families in poverty areas. Accordingly, this study mainly focuses on supporting physiotherapy process of children with CP living in poverty in Turkey. In order to reach this aim, an Affordable Home-based Support Environment for Cerebral Palsy (AHSEN-CP) was developed according to the specific requirements of the target user group with CP.

1.2 Purpose of the Study

The main purpose of this study is to design and develop a game-base therapy support system for home use that is affordable for families who have children with CP and provides a detailed report for tracking the progress of the child after each game play. Hence, it is aimed to support the treatment process of children with CP by providing an exercise environment that can be used anytime and from anywhere. This support is investigated in three categories: support for patients, families and physiotherapists.

1.3 Significance of the Study

In comparison with most of the developed countries, there is a higher number of patients with CP in Turkey [9].In spite of that situation, in Turkey there are very limited number of studies and practices on virtual reality games for children with CP. This study is one of the initiator studies on this topic in Turkey. While performing a demonstration of the game in Hacettepe University, Physical Therapy and Rehabilitation Department, a physiotherapist stated that she was happy to see a virtual rehabilitation game in Turkey similar to the ones she saw in a conference organized in a foreign country. Also, she was pleased with easy-to-use interface of the system that does not require any sensors and other apparatus to wear.

Most of the existing virtual rehabilitation systems described in the literature [12] [19] [22] [23] [24] are not easily affordable. Accordingly, the AHSEN-CP aims to provide cheaper solutions to support people having very limited access or no chance to access to such systems. In other words, physiotherapists can provide this game environment (AHSEN-CP) to their patients living in rural areas as well.

AHSEN-CP consists of an easy-to-use menu by which the parents or even the children can customize the game according to the physiotherapist's suggestions. After each game play, patient information, patient's score and the values entered through the game menu such as game speed, game duration and size of the game objects are sent to the physiotherapist's e-mail address. Based on this information, the physiotherapist can analyze the patient's progress during the game play and suggest different customization parameter values for improving the progress of the

patient for the next game play sessions. Hence, unlike most of the existing systems, the proposed approach provides a customizable in-home usage.

Children who have to take a long-term physiotherapy treatment may get bored of repeating home exercises and be unwilling to exercise. Although adults are supposed to be more conscious than children, a study shows that even most of the adults don't exercise regularly [13]. The main reason behind using virtual reality concept in this study is to increase willingness and excitement for performing exercises at home. Accordingly, one of the research questions in this study is "Does the proposed home-based therapy game system motivate patients with CP to perform exercises at home?"

The parents are required to follow up their children and participate in the treatment when needed [9]. Since children may not be awake to the necessity of doing exercises at home, they may refuse it. They may also not do the exercises properly, which may result in decline instead of improvement in movement skills and posture. Hence, it is the parents' responsibility to direct children for performing the exercises properly. It is sometimes difficult to convince the child for doing the exercises. It is also difficult for parents to allocate time at home for these exercises when they have other responsibilities. In addition to these problems, therapy costs are a burden for the parents, especially for those living in poverty. Hence, a child's therapy is a difficult process for the parents as well as for the children. In order to improve the progress of the therapy treatments, the level of support for the parents is also an important issue. For this reason, this study aims to support families who have children with CP. Accordingly, the second research question of this study is "Does the proposed home-based therapy game system support families who have children with CP for helping their child exercise at home?"

In addition, physiotherapists have to follow up several patients and it is sometimes difficult for them to track detailed information about each patient to see whether they are performing the exercises at home properly. Hence, supporting physiotherapists to track each patient is another important consideration of this process. Accordingly, another research question of this study is "Does the proposed system support

physiotherapists for following children's home exercises who are having CP treatment?"

1.4 Limitations

While developing such a supporting environment, the proposed system also concerns about the improvement of upper extremity skills of the patients. The proposed home-based therapy system does not consist of any sensors or 3D cameras. For this reason, it cannot recognize and track specific parts of the body. The patient's arm cannot be recognized automatically by the game so the game was implemented the way that it forces the patient to use her/his arm to reach objects in the game. One of our study's focuses is whether or not the basic system we proposed is feasible for supporting routine upper extremity treatment and provides improvement in patient's affected skills.

This study is conducted with two patients from Hacettepe University, Physical Therapy and Rehabilitation Department. Small number of patients is a limitation for doing a scientific data evaluation.

If the games are not played properly, for example if the patient stays too close to the web cam, or one of the other family members play the games instead of/with the patient before sending the report to the physiotherapist, the reports may mislead the physiotherapist.

1.5 Thesis Organization

This thesis is organized as follows: Chapter 2 contains the background of this study; Chapter 3 describes the research methodology used in the study and Chapter 4 details the system development phase. In Chapter 5, collected data are evaluated and finally conclusion and discussion part of the study is given in Chapter 6.

CHAPTER 2

LITERATURE REVIEW

In this chapter, firstly, some brief information about CP and the treatment methods for children with CP are presented. Then, the virtual reality concept and the advantages/limitations/disadvantages of using virtual reality systems as therapy tools as opposed to using the conventional therapy methods are explained and discussed. Finally, an overall picture of the literature is given.

2.1 Cerebral Palsy

In this part, general information about CP, hemiparetic CP and CP treatment are given. The children's perspective to the CP therapy process is discussed.

2.1.1 About Cerebral Palsy and Hemiparesis

CP is described as permanent but non-progressive neuromuscular, musculoskeletal and sensory system impairments that occur after the immature brain gets affected by various factors [1]. Although such ailments are not progressive, the inabilities that they cause may progress [9].

There are a few classifications of CP. One of these classifications is made according to the extremity it affects. This study focuses on hemiparetic CP which means only one side (right or left) of the patient's lower and upper extremities is affected. In most cases of hemiparesis, the upper extremity is more affected than the lower extremity [1].

2.1.2 Hemiparesis Treatment

There are various CP treatment approaches which will be chosen by the physiotherapist depending on the cerebral palsy type that the patient has [1].Since

this study proposes a system that can be used only for children with hemiparesis, this section focuses on their physiotherapy.

The muscular tone of the affected side of children with hemiparesis shows serious increase in time [1]. Also, because of preferring to use the non-affected side during pediatric development, an asymmetry appears on children's body and extremities [1]. The main goals of hemiparesis treatment are to improve functionality of the affected side and attaining symmetry on posture and movements [1]. To improve the functionality and the proper usage of extremities, primarily muscle tone of proximal zone and pelvis zone muscles should be regulated and dynamism and stabilization of these zones should be improved [1]. Since the treatment changes depending on the circumstance of each patient [9], it is important for the physiotherapists to choose best-fitting practices.

2.1.3 Therapy from Children's Point of View

Children with CP may not be able to join their friends while playing some of the games since they cannot handle the games which require specific skills like speed and balance. They also have less time to play since they should attend the therapy sessions in therapy centers. Because of these reasons, children with CP need to play more. Santos and Ferreira (2013) indicates that children with chronic diseases who receive physiotherapy want to play more during therapy sessions [4]. As a result, to improve the willingness of children for performing exercises, game-like exercises can be used as the studies show that virtual rehabilitation games are more entertaining than the routine exercises in the patients' opinion [6] [15].

2.2 Virtual Reality

At the beginning of this section, the Virtual Reality (VR) technology is basically introduced. Then it is discussed in terms of its usage for developing therapy systems, and feasibilities of the existing systems are evaluated. In the last part, the results obtained from the literature review are presented.

2.2.1 About Virtual Reality

Burdea and Coiffet (2003) define virtual reality (VR) as "*It is a simulation in which computer graphics is used to create a realistic-looking world. Moreover, the synthetic world is not static, but responds to the user's input (gesture, verbal command, etc.). This defines a key feature of virtual reality, which is real-time interactivity*."[2].

2.2.2 Using Virtual Reality Systems as Therapy Tools

Repetition of the activities and patient's motivation are two important aspects for improving motor skills [1] [7]. Hence, especially for children, playing games that involves repetitive physical exercises is a helpful and fun treatment alternative. VR games can be a good alternative for physiotherapy in terms of allowing repetition of the same task [10]. VR games motivate patients to exercise [15]. Bryanton et al., 2006 reported that patients with CP had fun while doing VR game exercises more than they were doing routine exercises [6]. Since the players can see themselves at the computer screen while interacting with the objects in VR games, VR adds realism to the games. By this way, patients engage in the game and perform the tasks in the game voluntarily [10].Using VR games in therapy is also a good way to record and analyze patients' performance for physiotherapists to follow up their patients easily [10]. If proper tools such as data gloves or sensors are used, it is possible to make precise measurements of patients' movements. Since VR technology can also give the opportunity of creating low-cost environments which can be distributed [10], VR games can also be used for providing home exercises to patients. Besides all these strengths, creating VR systems for rehabilitation is a complex and serious process which requires both engineering and medical knowledge [10].

2.2.3 Existing Virtual Reality Systems

There are some commercial VR game systems or tools developed for non-medical purposes like Nintendo Wii and Sony Eye Toy which is a web cam to attach to Playstation2 gaming console that is not affordable for poor families. Games in these systems cannot be adapted according to the specific physiotherapy requirements of each patient. Since children with CP may not handle the speed and difficulty of the

game, they may become demotivated for exercising. Also, families living in poverty may not afford these systems for home-use. A boxing game on Wii system is shown in Figure 2.1.

Figure 2.1 A boxing game on Wii system [22]

SeeMe is a commercial virtual rehabilitation software which can be used with a PC and a web cam [27]. Since it does not require any apparatus to wear, it is convenient to use. Real-time adaptation of the games by the physiotherapist based on the patient's performance is possible, on the other hand it requires the physiotherapist's participation in the game session to use this option. In addition, this system can be purchased at a very high cost.

Mandala® Gesture Xtreme IREX is another example of commercial systems. It requires a special camera at a high cost. "Birds and Balls" game which can be played by Mandala® Gesture Xtreme IREX system is shown in Figure 2.2 [12].

Figure 2.2 Birds and Balls Game [12]

Most of the non-commercial rehabilitation aimed systems that are developed by researchers require apparatus such as robotic arm, sensors and data gloves [19] [23] [25] [26]. These tools may be inconvenient to use at home. Furthermore, these systems are still not affordable for poor families although they are relatively inexpensive. There are only a few examples of the systems developed for rehabilitation purposes which are used without such expensive tools.

VirHab is an adaptable system which is affordable even by poor families. However, it requires blue background and to wear white robe and black vest in order to be able to track movements of patients. Besides, it does not create any performance report after the game [24].

2.3 Summary of the Literature

When the literature is reviewed, one can see several studies on rehabilitation using virtual reality systems because they are fun to use, they can provide performance reporting and a realistic game environment which engages patients in the game, thus

helps them forget that they are exercising. On the other hand, only a few of these systems are both suitable for home use and can be afforded by poor families. Hence, there is a need for an affordable and adaptable therapy system which can be used at home without the surveillance of a physiotherapist.

CHAPTER 3

METHODOLOGY

In this study Action Research Methodology has been utilized. Action research is the methodology which consists of defining the problem, collecting data and evaluating data to determine the required action to solve the problem, and taking action [21]. As it is clear in Figure 3.1, the study was conducted in two steps. Firstly, AHSEN-CP was designed and developed according to the specific requirements of the domain. Afterwards, the research study was conducted. In this chapter the details of each step of this study are described.

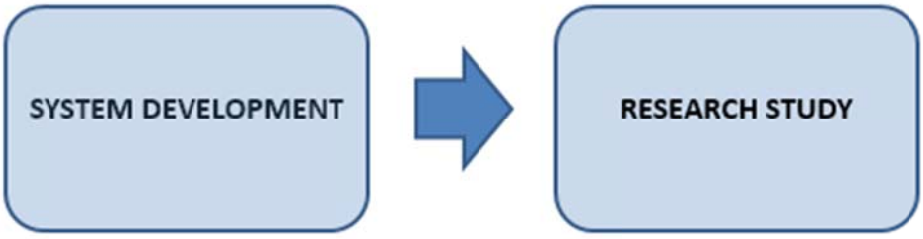

Figure 3.1 Study Method

3.1 System Development

As it is clear in Figure 3.2, the system development phase of the study follows several steps namely requirements collection, game design, pilot study, domain expert approval on design, and game development. During the requirements collection phase, several interview sessions have been conducted with the domain experts to better understand the specific requirements of the system.

Figure 3.2 System Development Approach for the Study

After the requirements collection and analyses phase, the game was designed. By having domain expert approval on the game design, the game was developed. Then the pilot study phase was started. The detailed information about system development is given in Chapter 4.

3.2 Research Study

This study includes the development of specialized software for children that have hemiparetic CP. Additionally, the effect of the developed system on this target group is analyzed experimentally. The main research questions of this study are set as follows:

RQ1. Does the proposed home-based therapy game system motivate patients with CP to perform exercises at home?

RQ2. Does the proposed home-based therapy game system support families who have children with CP for helping their children exercise at home?

RQ3. Does the proposed system support physiotherapists for following up children's home exercises who are having CP treatment?

RQ4. Does the proposed system affect progress of the patients with CP positively during the therapy treatment?

In order to answer these research questions, the research model of the study that is shown in Figure 3.3 was prepared. Figure 3.4 shows the relationship between data collected during the research study steps, and the research questions.

Figure 3.3. Research Study Model

RESEARCH QUESTION	COLLECTED DATA
Does the proposed home-based therapy game system motivate patients with CP to perform exercises at home?	✓ Interviews with Patients ✓ Interviews with Parents ✓ Game Reports
Does the proposed home-based therapy game system support families that have children with CP for helping their child exercise at home?	✓ Interviews with Parents
Does the proposed system support physiotherapists for following children's home exercises who are getting CP treatment?	✓ Interview with the Physiotherapist
Does the proposed system affect progress of the patients with CP positively during the therapy treatment?	✓ Interviews with Patients ✓ Interviews with Parents ✓ Interview with the Physiotherapist ✓ QUEST Results

Figure 3.4. Relationship between Research Questions and Collected Data

By the suggestion of the domain experts, the QUEST Test was applied to the patients at the beginning of the study as pre-test and repeated at the end of the study as post-test to evaluate the changes on their upper extremity skills. After developing the system as described in Chapter 4, a setup session was conducted at the hospital with the patients who participated in this study. One of the aims of this session was to introduce AHSEN-CP to the participants. Since each patient should play the game with different customizations, the setup session was also conducted for physiotherapist to determine game customizations such as its speed and duration for each patient according to their specific requirements. After this setup session, the patients were suggested to play the game once a day for 4 weeks.

Since rearranging the therapy program according to the patient's performance is essential [1], after each game play session, a report which shows patient's performance during the game play is sent to the physiotherapist by AHSEN-CP. These reports are saved and evaluated by the physiotherapist to determine new game customizations if there is a remarkable change in the patient's performance. Since with our system it is not possible to make any precise tracking of patients' movements in specific areas, rather than showing indication of the improvement on patient's motor skills, the game reports can show a general improvement on patient's

performance. Hence, these reports are not used for evaluating the patients' improvement mathematically.

Following a 4 week-period of game play, 3 different semi structured interviews were conducted with patients (Appendix A), parents (Appendix C) and physiotherapists (Appendix E) to evaluate their satisfaction levels with AHSEN-CP. Also observations of patients, parents and physiotherapists were asked in the interviews since the observation is an important assessment parameter in physiotherapy [9]. Each interview took 5-15 minutes depending on the answers. The interviews were recorded and transcribed for further analyses.

Patients

The required information about the participants is given in Table 3.1. In the next sections, the participants are named as Patient 1 and Patient 2 depending on this table. The study started with three patients but one of the patients did not continue participating in the study since he was not available anymore because of some personal reasons. Yet, his mother told that she was very pleased by AHSEN-CP since it provided an enjoyable environment for doing exercises.

Table 3.1 Participants of the Study

Participant No	Sex	Age	Hemiparetic Arm	GMFCS	MACS
1	Female	10	Left	1	1
2	Male	7	Right	1	2

In Table 3.1, GMFCS stands for Gross Motor Function Classification System and MACS stands for Manual Ability Classification System. Both of these are used for defining the severity of impairments. The higher the number is the more the patients are affected [17]. Depending on the physiotherapist's observation and the patients' GMFCS and MACS values, in the setup session, the physiotherapist decided that Patient 1 was to play AHSEN-CP games for 10 minutes and Patient 2 was to play AHSEN-CP games for 15 minutes in each day.

Although the patients suggested to play AHSEN-CP games once a day, Patient 1 played the games for eleven times, and Patient 2 played it for eight times according to the reports sent to the physiotherapist. This data is known to be incorrect since Patient 2 indicated that sometimes she has problems with the internet connection and she could not send the report although she played the games in most of the days.

CHAPTER 4

SYSTEM DEVELOPMENT

4.1 Requirements Collection Phase

To determine the requirements, two meetings were held with a group which consisted of four physiotherapy experts and three experts studying on computer sciences. In these meetings, they expressed that the system should be suitable for home use to support the physiotherapy processes carried out in hospitals. Since the games will be afforded by the parents and in Turkey there are too many families who live in poverty and having children with CP, the group agreed on a basic and consequently inexpensive system, which can only be used for performing upper extremity exercises. The physiotherapy experts remarked that the games should be tailored depending on the patients. As a result of these meetings, a basic system was offered for children with hemiparesis to do upper extremity exercises easily at home.

4.2 Game Design and Approval of Domain Experts

Based on the requirements specified by the domain experts, a pilot version of the system was developed and it was evaluated by a patient, his mother and the domain experts. When the patient's opinions about the game were asked, he told that he had fun while playing the games. His mother told that her son showed interest in the games. They did not have any advice about the game. After seeing the pilot version, the physiotherapy experts advised adding enthusing voices like "Wonderful!" or "You are doing very well." Since the main goal of the exercises in the game should be making patients raise their arms at as high positions as possible, they declared that there should be a line where the objects will disappear when it was reached, and it should be placed in the games according to the patient's height. Based on the domain experts' advices, the level designs of the games were elaborated. A photograph taken while the pilot version of the games were being played is given in Figure 4.1.

Figure 4.1 Pilot Study of AHSEN-CP

System overview is shown in Figure 4.2. Activity diagram of AHSEN-CP created using "Visual Paradigm for UML Community Edition" is shown in Figure 4.3 [11]. Use case diagram of AHSEN-CP is shown in Figure 4.4.

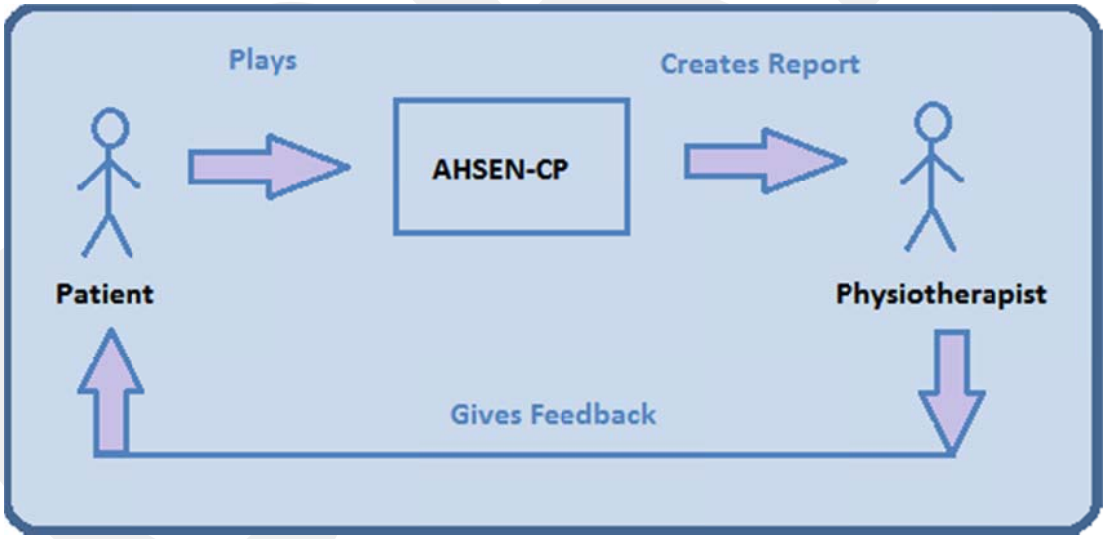

Figure 4.2 Overview of the Proposed System

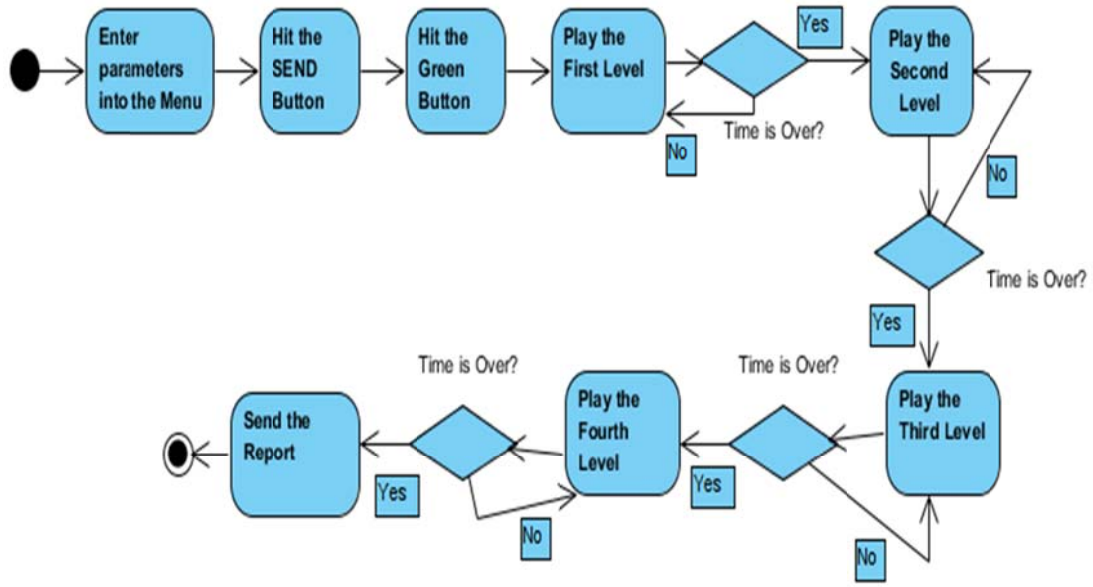

Figure 4.3 Activity Diagram of AHSEN-CP

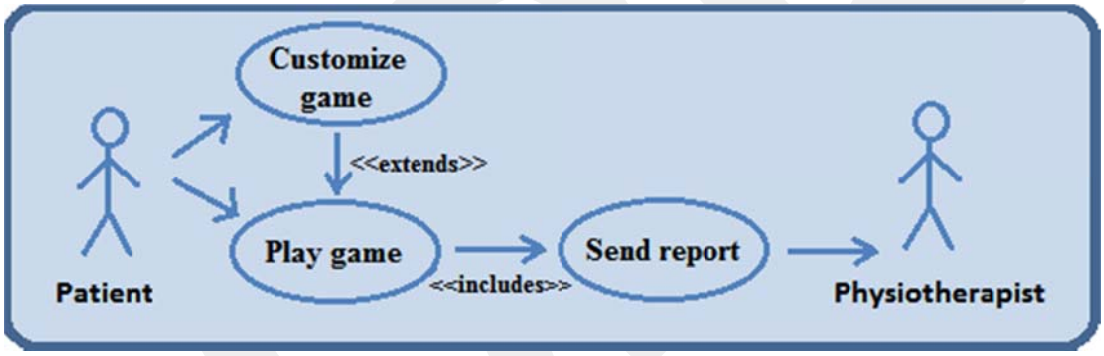

Figure 4.4 Use Case Diagram of AHSEN-CP

4.3 Game Development

Technical Features of the Game

The game was programmed by Actionscript 3 by using Adobe Flash Professional CS6. An online tutorial [5] was modified to develop the game according to the requirements which are described in section 4.1. Since our aim was to evaluate the feasibility of the systems that even families living in poverty can attain we used a basic system in our study. The game requires only a PC and a web cam if the PC doesn't have an internal camera. Though the game can be played without an internet connection, the connection is required to send the report to the physiotherapist at the end of the game.

The game can be played by running an executable file without any installation. Adobe Flash Player must be installed on PC to play the game. It is required to allow web cam connection at the beginning of the game.

Since no sensors or 3D cameras are used in our system, it cannot recognize and track specific parts of the body. The patient's arm cannot be recognized automatically by the game, so the game was implemented the way that it forces the patient to use her/his arm to reach objects in the game. By this way patients can do upper extremity exercises, on the other hand the game cannot be used for doing hand exercises. Since the game is not able to control which arm is used, the patient enters which arm he/she will be using during the game into the menu at the beginning of the game. Hence it is assumed that the patient uses only the required arm during the game.

Game Interface

The CP treatment changes depending on various criteria like affected parts, socioeconomic factors and impairment levels [9]. Also, the physiotherapist should frequently follow-up the patient and change the treatment when needed [1]. Since home-based computer games are played without participation of physiotherapist, in the game, there should be a system by which the physiotherapist can follow up the patient's performance and provide feedback to family so that the patient can adjust the game depending on the physiotherapist's suggestion. Based on this idea, a menu which provides adjusting the game at the beginning of each game play based on physiotherapist's suggestions and a reporting system which provides physiotherapists to follow up the patient were added to the game.

The menu that is shown in Figure 4.5 includes text fields for entering the values of game speed, object (balloons, balls, and apples) size and time period which physiotherapists determine. It also includes text fields to enter patient's name, patient's height and hemiparetic arm information ("right" or "left"). Personal information is used in the report that is created at the end of the game. Patient's height is also used for calculating the level of the red line at which the falling objects will disappear when they reach the line. Such a line is needed in the game to improve patient's reaching movement by preventing the patient from reaching the objects at

low levels and constraining them to reach the objects when they are only in higher levels before they disappear. A screenshot of the line can be seen in Figure 4.6.

Figure 4.5 Form in AHSEN-CP

Figure 4.6 The Red Line

Game Levels

The game consists of four levels. Since repetition is an important aspect in CP therapy [1] [7], one of the main aims of the game is to make the patient play the game during the time period physiotherapist suggests. So the game levels don't end when player reaches a specific score or achieves a specific goal. Instead, each of four levels runs during the quarter of entered time period so the patient plays the game during the time period physiotherapist suggests. Score is shown at game screen only to motivate the player to play the game more actively. Since the game should be played once with the right arm, once with the left arm in each home therapy session, difference between the score reached with the hemiparetic arm and the other arm may cause the child to be more willing to get high scores with hemiparetic arm.

In the first level, there are bombs and different colored balloons falling down. Score increases by 1 when each balloon is popped and decreases by 3 when each bomb is popped. Figure 4.7 shows a screenshot from level 1.

Figure 4.7 First Level of AHSEN-CP Games

In the second level, there is a basketball and a basket. Score increases by 1 when the basketball is thrown into the basket and decreases by 3 when the basketball falls onto the red line. A screenshot from the second level is shown in Figure 4.8.

Figure 4.8 Second Level of AHSEN-CP Games

In the third level which is shown in Figure 4.9, the score increases by 1 when each apple is picked. There is no score decrease in that level.

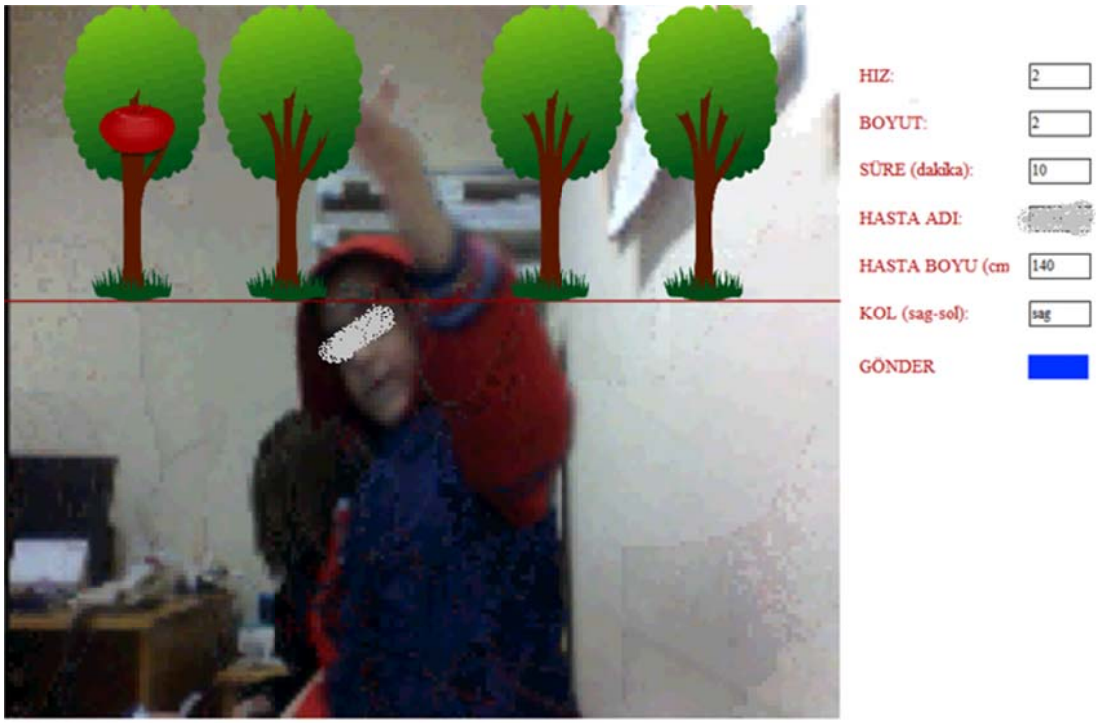

Figure 4.9 Third Level of AHSEN-CP Games

In the last level there is a ball and a stick. When the ball hits the stick, it bounces, so it is prevented from falling down to the ground. When the arm is moved, the stick follows it. So the player should align her/his hand to the position to which the ball will fall. She/he needs to hold her/his hand at a higher position than the level of the red line in order to be recognized by the camera. The score increases by one at each bounce on the stick, and decreases by 3 when the ball falls down to the ground. A screenshot from the fourth level is shown in Figure 4.10.

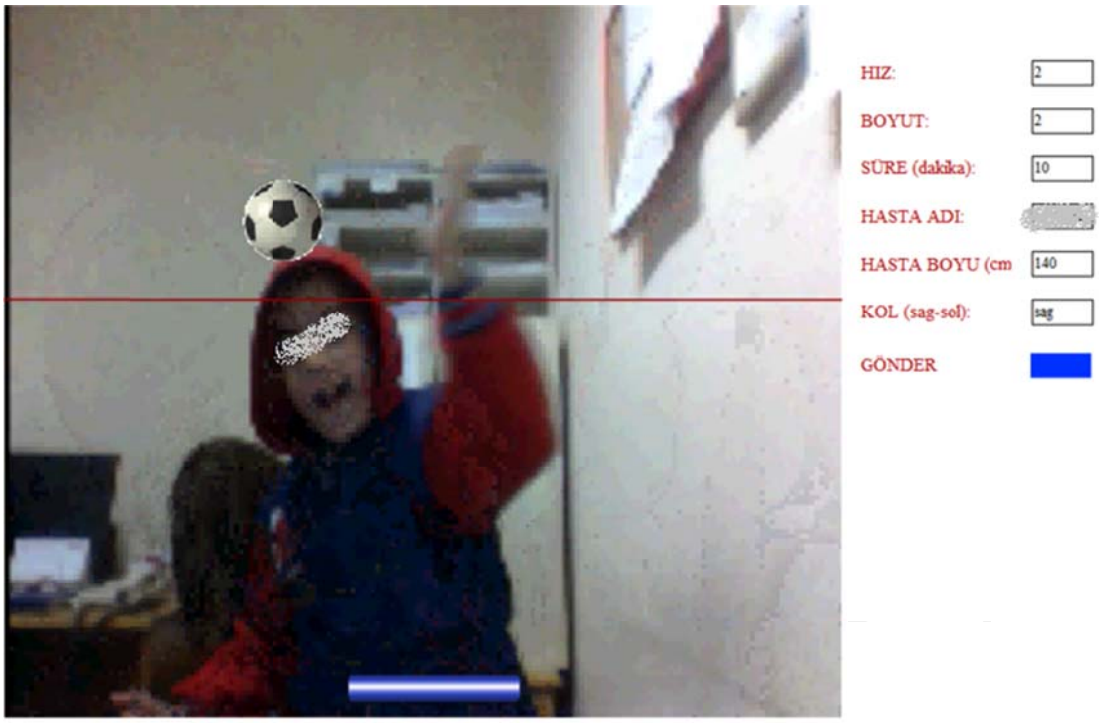

Figure 4.10 Fourth Level of AHSEN-CP Games

At the end of each level, a voice is heard which congratulates the player by saying one of "Wonderful!", "You're doing very well." or "Congratulations!" expressions that is chosen randomly. To add realism to the game, sounds like bouncing and popping effects were added.

When all the levels are completed, the game opens the PC's default mail program to send the report that is created to the physiotherapist. The e-mail's subject and text fields are automatically composed by the game using the values that are entered by the player at the beginning of the game. A sample report is shown in Figure 4.11.