ENS 491-492 – Graduation Project

Draft Final Report

Project Title: Serious Games for Children with Cerebral Palsy

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1. EXECUTIVE SUMMARY

For children with cerebral palsy, exercise and physical therapy are essential to increase their quality of life. As children, they get bored easily and want to play games. We wanted to aid their therapy while providing entertainment. We also wanted to be able to document aspects of their progress to aid physical therapists.

We decided to focus on balance training. Our game consists of mazes that are fixed to a platform. Through a Wii Board, the child is able to tilt this platform and in doing so move the character. They collect rewards (grapes) as they go on which determines their score and the aim is to reach a point on the map (cave). The game overall is jungle-themed with interactive music and sounds.

Since most of our meetings with therapists of children with CP told us that the therapist wanted more information regarding the child's progress, that was the main problem we decided to focus on.

Firstly, we wanted the therapist to be able to observe the movement and the progress of the child through the game. This is the biggest problem we have addressed with our project. With reports that are presented which are generated using a database and in so doing we are able to provide an insight into the child's movements. These reports contain a variety of information that will be explained in detail in this report.

Secondly, we also wanted to provide some customization for the therapist to tweak the game. To do this, we have provided two parameters the therapist can influence which allows the therapist to determine what movements the child should be encouraged to do.

In conclusion, our game needed to be entertaining to children and provide an outlet for their physical therapy while being informative and helpful to their therapists.

2. PROBLEM STATEMENT

Cerebral palsy (CP) is a collection of disabilities that impact a person's ability to move, balance, and maintain posture. The most prevalent motor disability in children is cerebral palsy. Cerebral refers to the brain and palsy refers to muscle weakness or difficulty using muscles.

Individuals with Cerebral Palsy (CP) have motor disorders that are commonly associated with changes in sensation, learning, body perception, communication, and behavior, all of which impair the individual's functionality. Because of these challenges in several sensorimotor domains, it is critical for people with cerebral palsy to have ongoing access to rehabilitation therapies. A person's capacity to regulate his or her muscles is harmed by CP, which is caused by faulty brain development or damage to the growing brain. The signs and symptoms of “severe CP” differ from one person to the next. A person with CP may require special equipment to walk or may not be able to walk even with a help of equipment and necessitating lifelong care. On the other hand, a person with “mild CP”, may walk in a tough way but not require any extra assistance. Though the exact symptoms of CP can fluctuate during a person's lifetime, the condition does not worsen.

In general, CP patients suffer from posture and movement problems. However, some patients also have some related conditions, for example, Cognitive comprehension challenges, some intellectual disabilities, sensory challenges, seizures (problems related to vision, hearing, or speech), etc. Although there is no definitive proven treatment method to overcome this disease, there are exercises and studies that can help CP patients live their

lives more easily and relieve them a little in their daily work. These exercises are generally done for muscle boosting strength and endurance, cardio, and flexibility, in addition, there are exercises to develop some cognitive skills too. Since CP patients are generally in the child age group, serious games are also used to make the exercises more effective and fun for patients.

New technologies offer intriguing possibilities for maintaining treatment for people with cerebral palsy through home-based telerehabilitation (HBTR). Serious games are a fun and successful method to support HBTR. Serious games which are designed for patients with disorders and which can be calibrated for the disorders individually like virtual reality (VR), mobile and computer games can incorporate a variety of learning elements with interactive motor and cognitive challenges in an engaging environment, allowing people with neurological disorders to practice motor skills in a repetitive, adaptive, meaningful, and challenging manner. Serious games, in general, are games that are specially designed for a certain disease and the treatment of disease, developed to make the patient's exercises more effective and enjoyable. These games should be able to be adjusted according to the type of disease, the purpose of the exercise and it must be able to set according to the specific needs of the patient. Those settings could be speed, the direction of play, time, dimensions and colors, and custom settings for the limbs and organs that the patient will use during the exercise. Another important point about these games is reporting. The game should collect the patient's performance, statistics and data about the patient that the therapist is curious about, during the game, and present it to the therapist as a report, knowing that it is an exercise and treatment during the game while the patient is playing the game.

To make such a game, we decided to use Unity. Unity is a cross-platform game engine developed by Unity Technologies. It supports both 2D and 3D graphics as well as interactive simulations and other experiences and scripting through C# and the drag-and-drop functionality. Unity is a potent game engine that provides its developers with a horde of vital built-in features. These include 3D rendering, physics, and collision detection. The presence of a built-in Visual Studio and its C# scripting API makes its learning curve smooth, and beginner-friendly. Along with being a game engine, Unity is also regarded as an Integrated Development Environment (IDE) which means that the developers have access to tools within an interface, all in one place.

All of these attributes make Unity the perfect game engine to build our games in. It removes a lot of constraints and optimizes time, the learning curve and quality.

During our research, we were able to learn a lot about the types of games being made by reading the International Journal of Serious Games. We have taken inspiration from a few previous works. In general, the biggest take-away from these projects were:

a) *What did they care about? What were the important information and data we needed to look for?*
b) *How did they go about making it fun? At the end of the day, we are still making a game and in our case a game for children. It was important to see what else was out there in this field.*
c) *What kind of hardware did they incorporate? How did they integrate this hardware into their game? Especially during our design phase these examples helped us a lot to conceptualize what was possible.*

Even though the games explained below are not all for CP, these examples were great in terms of showing us what was out there and what was important in designing a serious game. All 3 of these games have unique aspects that we found to be helpful to our project.

1. FarMyo A Serious Game for Hand and Wrist Rehabilitation Using a Low-Cost Electromyography Device

FarMyo was made by Thiago Vinícius Vieira Batista, Liliane dos Santos Machado, Ana Maria Gondim Valença, Ronei Marcos de Moraes and it is Brazilian production.

The purpose of this game is to help the rehabilitation of people who have had a stroke, and more specifically the rehabilitation of their hands and wrists. The desired movements are below:

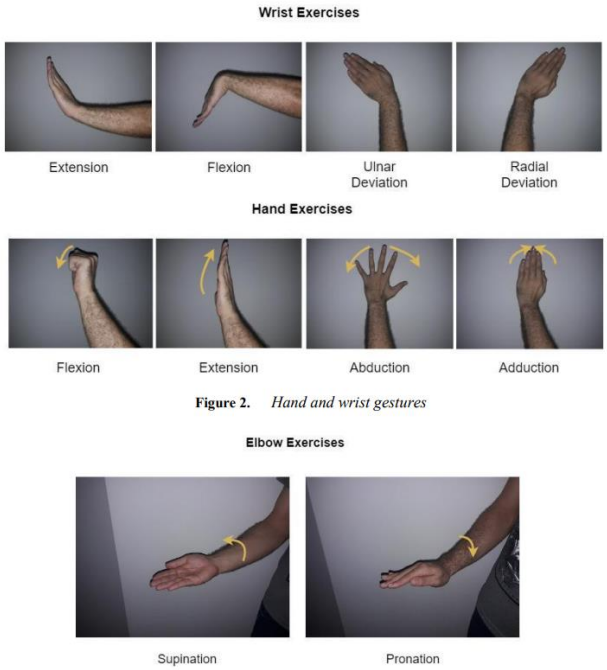


Figure 2. *Hand and wrist gestures*

Figure 1. Elbow exercises

The gesture recognition is done by Electromyography, which is a technique that consists in the measurement of the electrical signals produced by the muscles when there is a stimulation of the motor units (MU).

For this serious game, the Myo Armband was used, a low-cost surface electromyography commercial device that provides raw data when reading user movements for elbow and finger movements, but a new model was implemented for wrist movements.

The game consists of an environment where the user can select one of three mini-games, each of them treating a different group of gestures. Aesthetically, the game is farm-themed, with an idyllic farmland scenery composed of structures that resemble a barn, a vegetable garden, and a henhouse. Graphical realism was not one of the priorities for the scenario of the game. The focus was on clear and simple elements that would ease the identification of elements of the scenario and of the activities to be performed. Story-wise, the game consists of the story of a farm owner, who produces different items and sells them. The user must help the owner collect or process the items in each mini-game to meet a daily quota. The game engines Unity3D and the Myo SDK were used to develop the game.

Figure 2. Game's main screen

1. The barn: illustrated by the red structure. It represents the game of corn collecting, which deals with elbow exercises that are important in the process of hand and wrist rehabilitation.

2. The henhouse: illustrated by the beige-colored structure. It contains the egg collecting game, which deals with exercises involving the fingers.

3. The vegetable garden: illustrated by the brown-stripped structure. It represents the fruit collection game, which deals with wrist exercises.

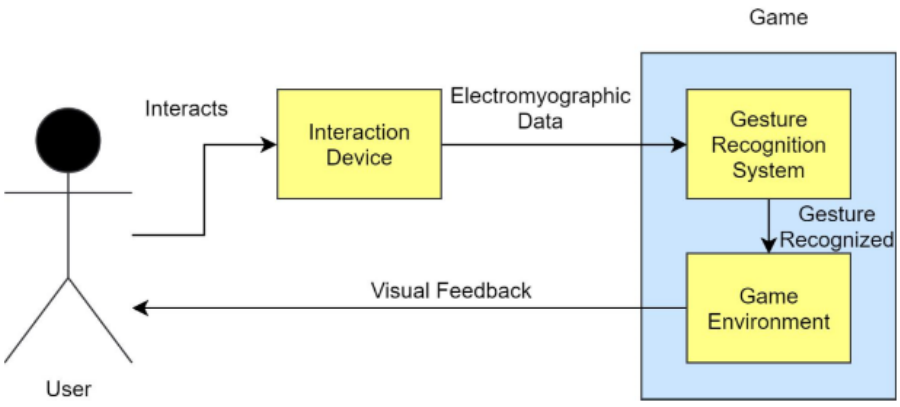


Figure 3. Architecture of the game integrated with the MYO system

The game also increases difficulty if an action is performed correctly and decreases difficulty when an action is unsuccessful. To improve patient motivation and engagement, resources to provide feedback to users were implemented: a display of daily quota, available in all scenes and mini-games, and a system of achievements.

To assert if the device is viable for patients in the process of rehabilitation, a test was performed with a voluntary individual who was in the process of recovery after a stroke. He was, at the time of the test, in the level 3 of the MRC scale. The test was performed with the

assistance of a rehabilitation professional. In the test, the individual was asked to perform some movements to verify if the device could capture the corresponding signals.

Finally, the patient stated that the device was comfortable and easy to use and that he could barely notice that he was wearing it, since the device weighs only 93 grams. He also stated that he would have no problem using it for a prolonged period of time and that he would be interested in playing a serious game for the purpose of rehabilitation.

This game was published in Vol. 6 No. 2 (2019) of International Journal of Serious Games on 25/06/2019.

We learned to care about desired movements and what to care about when it comes to hardware (especially weight which was later confirmed by therapists we had meetings with) which influenced the course of our project during the design phase and was one of the key factors in helping us decide to do a balance-based game.

Also, this game had music which was something we hadn't thought about. We did some research and found an article called "Development of Serious Games for Music Education" and learned a lot of things but mainly that the music children find to be is not too loud, chipper and happy but also relaxing. So, we asked a friend to help as he is a jazz conservatory student who specializes in video game music and sounds.

2. Sensamove and Their Gamified Software

Sensamove is a company which develops and produces innovative interactive various products focuses on the improvement and well-being of people in need of therapy. MiniBoard is a product of Sensamove, focusing on physiotherapy of children by combining data collection and gamification with its' accompanying software and various components beneficial for adjusting degree, delivering fun and health environment for the physiotherapy of children.

The Sensbalance MiniBoard combines the interactive training software and exercise games with the well-known benefits of a conventional wobble board. With easy exchangeable accessories the tilting angle and exercise difficulty can be customized.

Figure 4. Miniboard and degree adjusters

This game was maybe the biggest inspiration during our design phase. The idea of a board that was used in balance training made sense. This product also had a maze. Our board is quite different from this game's board, but we were heavily inspired from the concept of this game.

3. Verocy Fish for Rehabilitation

This is a game designed for physical rehabilitation for the CP patients. It is a game supporting Kinect which is a Virtual Reality Game equipment. It is a game which is available online, with multiplayer mode.

The game is a generally about that a player enters a sea world and uses his arm and hand to pilot their Verocy Fish. In order to play, the patient only needs to move his/her arms and hands. The patient moves the fish by moving their hand and throughout the game the aim is to help the fish to hunt avoiding prey to a larger fish or another fish.

This game as an exercise helps the patient to improve the upper extremity skills such has moving hands and arms; it also helps with the muscular Endurance and Mobility considerations. The other thing that game provides is the data collection. Physical therapists can monitor patient metrics such as range of motion and joint rotations.

Figure 5. Verocy fish gameplay

Data collection, like most serious games was an essential part of this game. This game was important because it was made for CP. We were really interested in its parameters and inspired by their metric range of motion we decided to incorporate the coordinates of the movement of the character as an indicator for a similar metric.

2.1 Objectives/Tasks

Our research and meeting with a physical therapist who was working with children with cerebral palsy made us realize what had to matter in our game. The problem is to have the ability for the therapist to review the progress of the child, which we learned was essential. To do so, we needed to extract data from the game, store it in a database and present it to the therapist.

We also needed a plan to keep children engaged. Our plan was to encourage the children by creating sounds and visual effects which are affirmative and congratulative for the progress that is being made, as well as a high score table, in which the children can try to improve their times and their scores. We are developing the game to be playable on any computer, which makes it really accessible. We are using a Wii Balance Board to play the game, as it focuses on the balance and posture exercises that we want children to complete.

All the information we've learnt made us realize our game had two main components: The Game and the Database.

The most important thing about the Game was the data acquisition and changeable parameters. The parameters we decided to have the therapist manipulate are *Sensitivity*, which determines how much movement is required to move the character and how sensitive the platform is to the movements of the child; and *Zone Management*, which allows the therapist to select one of 4 zones the rewards will be accumulated in, in order to encourage the child to use movements required to access those rewards more frequently.

Also, from within the game we needed to include the coordinates traveled, time and score in the reports.

The most important aspect of the Database was getting this data from Unity and compiling it in a way that makes sense and displaying it within the game which means sending it back to Unity.

With our goals realized, we built the base of the game.

2.2 Realistic Constraints

- Economic: We bought a Wii Board to test and calibrate our game with respect to it. The price was 300 TL.
- Environmental: This is a software project so it doesn't particularly have an environmental effect other than electricity computers use every day.
- Health and Safety: The product is a treatment tool so the product will be used by patients. It will be used under the supervision of a therapist in order to prevent any uncontrolled situation or a situation that will endanger the health of the user.
- Manufacturability: This product is a project which will be manufactured as a software. There is no need for a large factory and laboratory. The hardware used needs to be replicable and cheap so what will be used will probably be a household computer. We also wanted the hardware component to be accessible from all over Turkey and that is one of the reasons we chose a Wii Board because it is available in most tech stores.
- Sustainability (social, economic and environmental)**:** To be economically sustainable, the easiest methods available was preferred such as simpler games that can easily be put together rather than using the equipment required by VR-based applications.

3. METHODOLOGY

For our main problem (which is providing information for the therapist) we had to do 3 things that we separated between members: We needed to build the database,

we needed to extract and work the data and we needed to create a menu screen that was able to display that data as a report.

- *Skeleton of the Game*

We used Unity's built-in 3D objects and custom assets for textures, colors, backgrounds and materials. We also used Unity's physics engine and collision detection.

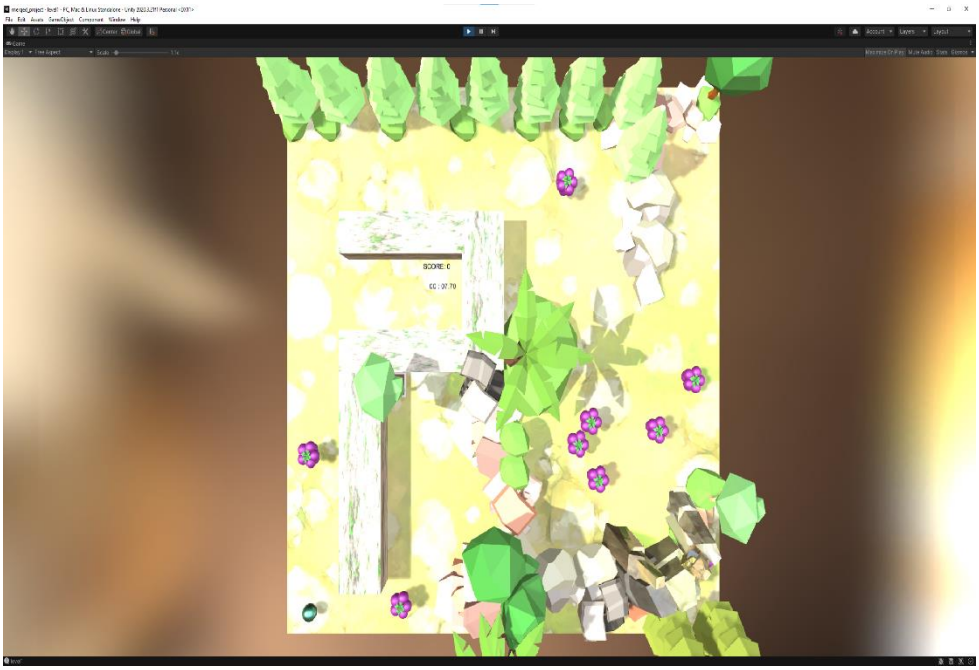


Figure 6. Game Level Photo

We have multiple custom C# scripts in place for determining controls, collision detection and its outcomes, custom triggers and scene transitions. Most everything mentioned below have been done by custom scripts.

In order to play this game with the Wii Balance Board, we have researched about different approached which enabled us to use Wii Balance Board and finally we have decided an already existing project called "*Wii Balance Walker*" was the perfect fit for our project. The existing software is easy to set-up as only a computer with

Bluetooth hardware is needed to read the inputs of the Wii Balance Board and enable us to control the keyboard while playing our game. The project interface is easy-to-use as there is a list of inputs which can be altered according to the player's choice and following that, opening the game results in the enjoyable gameplay which focuses on the player's balance and his/her movements. The traversal is much easier compared to playing with a keyboard and the sensitivity to the weight shift can also be adjusted.

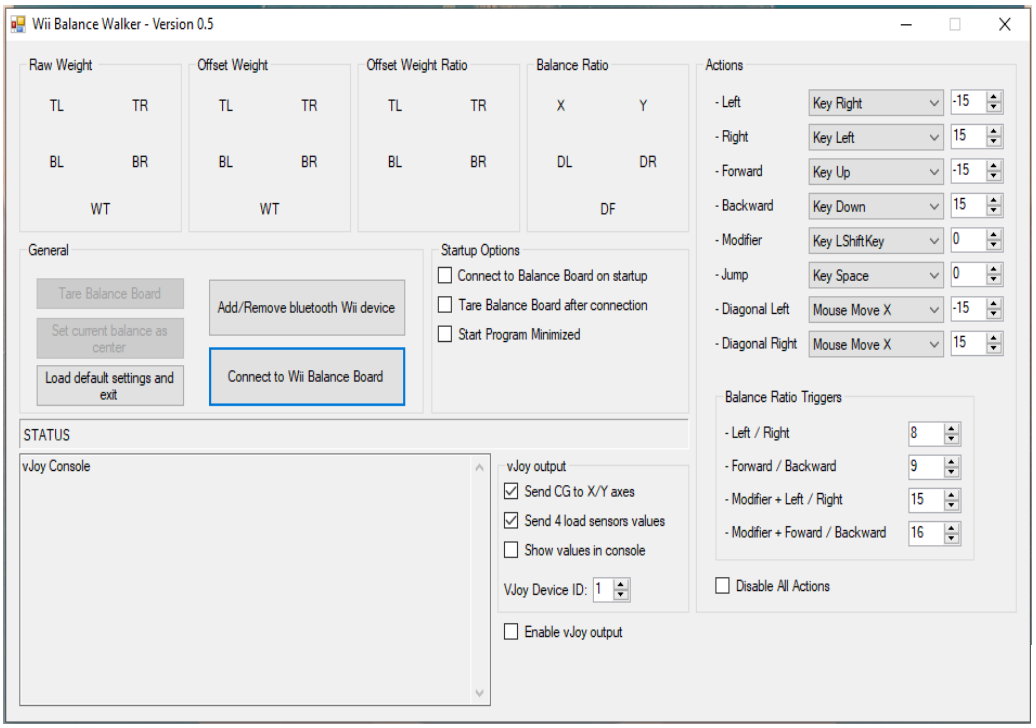


Figure 7. Wii Balance Walker Interface

- *Menu*

Almost every game has a menu for players to customize settings. Our menu accommodates both the therapist and player. When we look at it by the therapist side, there are two types of panels designed for him. One of them is a parameter menu where parameters can be changed, and the other is a report interface where patient reports can be viewed. In order to build this report interface, we developed a React.js interface for our project and we directed the user to this interface via a button in the game. When this interface is opened the therapist accesses the reports from the menu

by entering their previously designated admin phrase. A list containing the usernames of the patients playing the game appears before the therapist, who can log in within the interface. Using this list, the therapist selects the patient whose reports he wants to access and reaches the list of the reports of that patient. There are individual reports for each level completed by all the children in their care. With the React.js project we established, our backend is in constant communication and this communication is achieved by using API. The framework we use for the API is FastAPI. In this way, by using FastAPI, our game enables us to communicate with our backend, our backend with the database, and the interface after being processed from the database again in the backend.

For children there is a login and signup pages. An internet connection is needed to log in or sign up but the game itself can be played without a connection. In such a case no report will be sent to the therapist. Since we decided to store the data in MongoDB and we use an API for this, we need to use the Internet for communication.

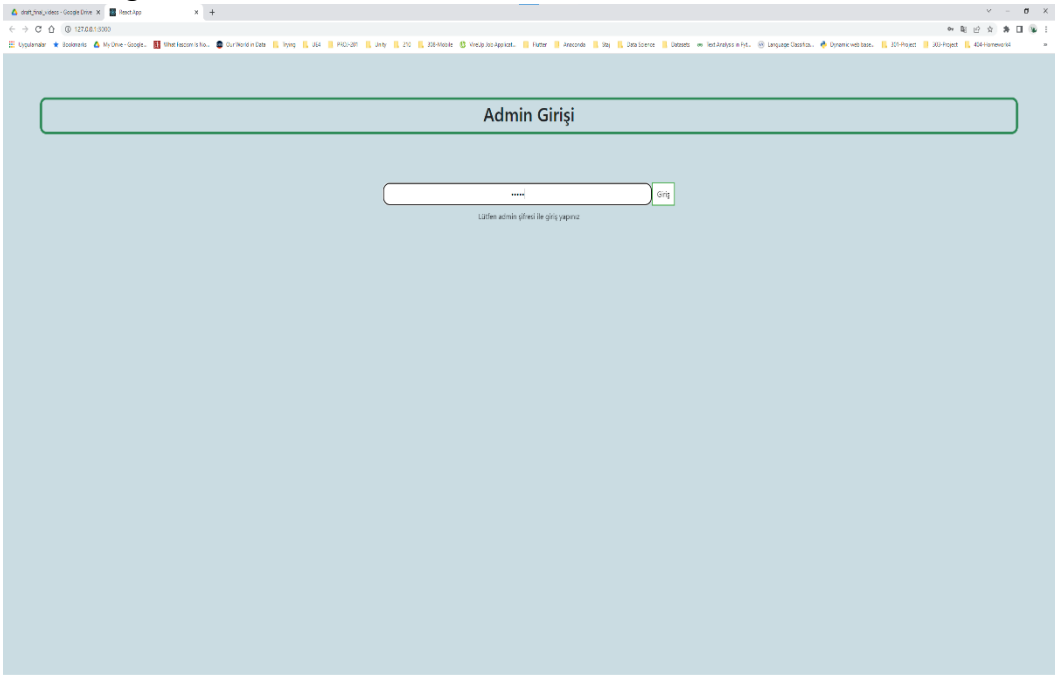


Figure 8. Reports Login Page

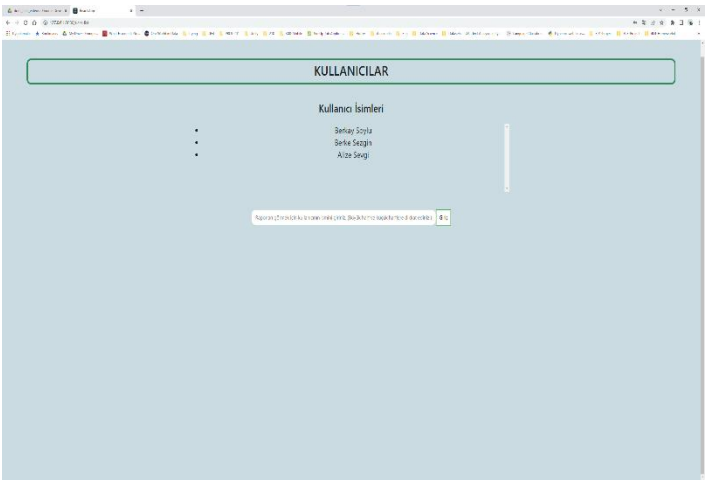


Figure 9. Reports Users Page

Figure 10. Report Page

- *Data*

We needed a timer. To do so, we used built-in properties like TimeSpan and created a GameController instance to govern. We decided to display a timer on the screen as well as at the end in the Game Over screen. Game Over screen is a scene that comes into the view as the current player finishes the level they are playing by reaching

to the goal position. A C# script is used in order to access all the variables that are initialized and their values, acquiring these variables and their values respectively and storing them as static variables enables the use of the variables across all scripts and scenes. In addition, the Game Over screen also acts as an informative page where the player can see their results; such as their time, difficulty and status. Game Over screen acts as a passage in order to inform the player as well as return to the Main Menu and Play Again options, which doesn't end the session but enables the player to change their current results.

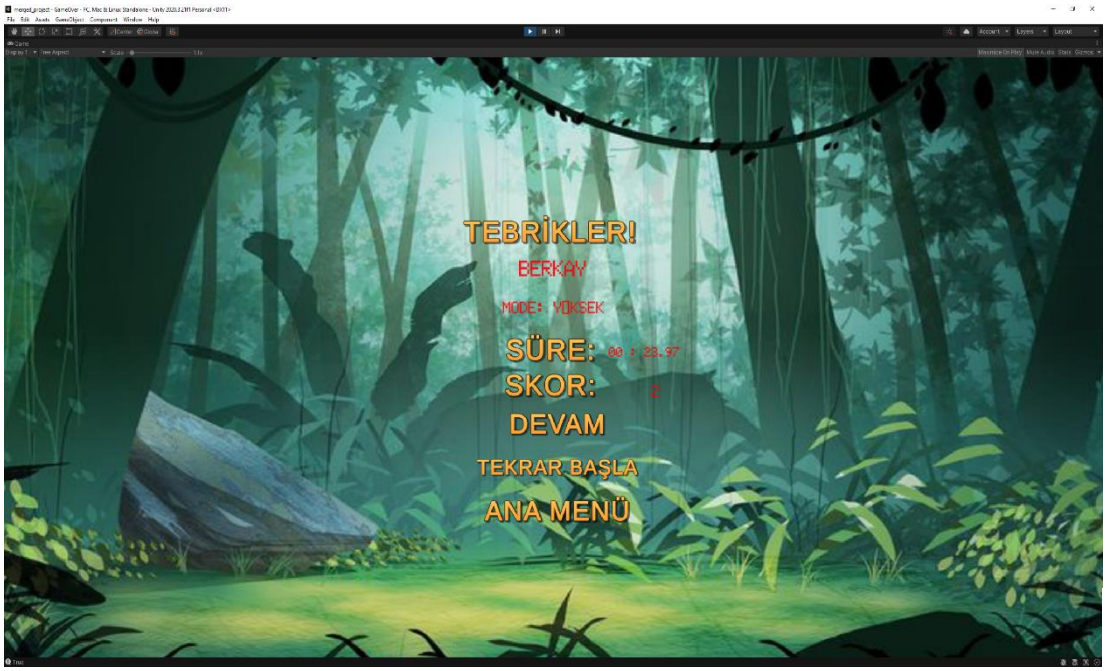


Figure 11. Game Over Screen

In the game, our player tries to reach a **goal** (cave) while collecting **rewards** (grapes) which are counted as a **score** in a maze-like structure by avoiding obstacles. We created a grape prefab and a corresponding spinning animation. This grape is the primary collectable. As the character touches the grape, the grape disappears and the

player's score increases. This data is sent to the Game Over screen the same way as above.

Figure 12. Grape Figure

The therapist can change the inputs in the game according to the needs of the patient. For example, if the patient has more balance problems using their right leg, the therapist can select one of the two east options which would generate more rewards in that particular region. This is to encourage the child to gather those rewards which makes them use their right leg more. This is what we call "zone management".

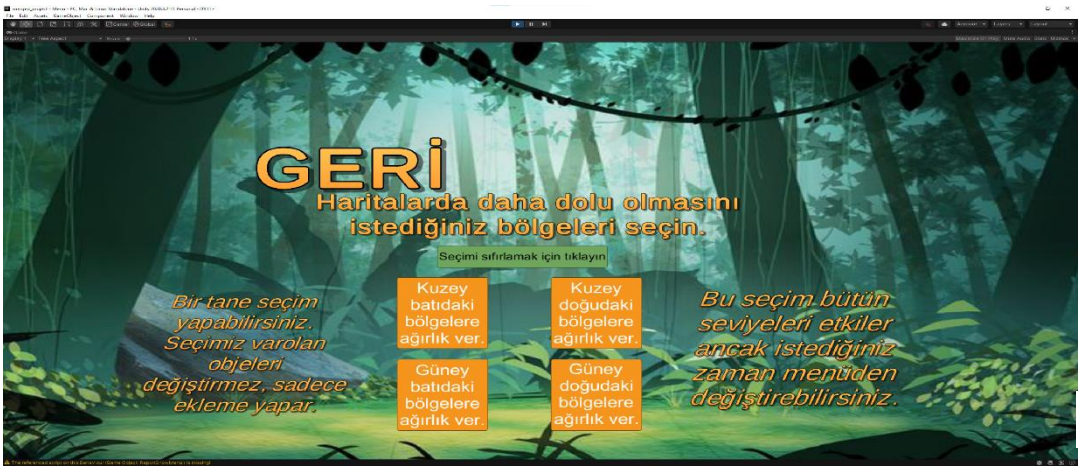


Figure 13. Region Parameter

Another input that the therapist can change is the sensitivity of movement, by increasing or decreasing the *drag* of the character, allowing it to move with higher or normal resistance. In this way, the patient needs to move more and with more force to control the movement of the character.

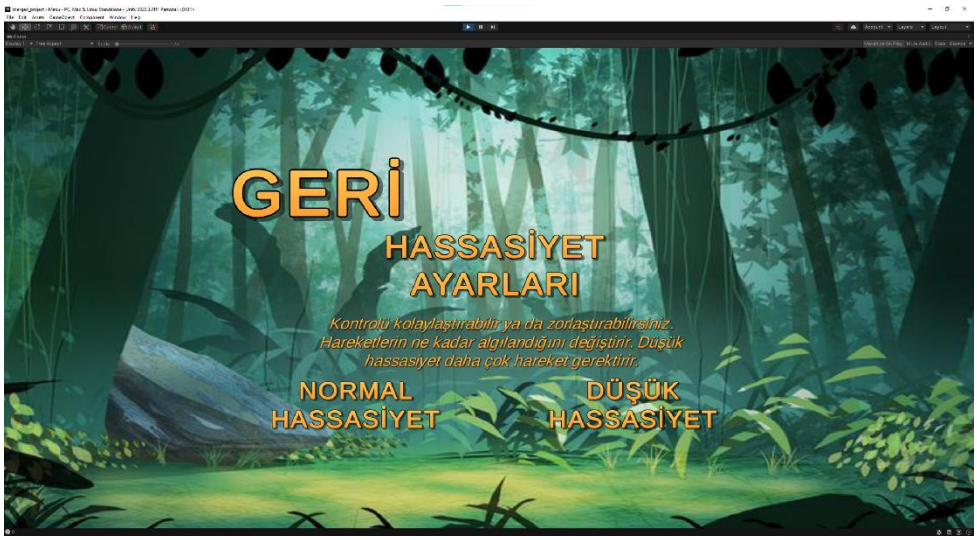


Figure 14. Sensitivity Parameter

- *Database*

To store and access the reports, we built the database with MongoDB, and created a functioning menu screen that had the therapist and player screens. Then we integrated the menu screen to the game that was now able to extract data. We also added the above-mentioned difficulty adjustments that can be accessed in the Therapist Menu. We do this by using something called “Player Preferences” which allows us to access this preference from every scene and script. These preferences can be changed from the menu after each level is completed.

After a level finishes, the Game Over screen comes into the scene displaying information about your current game, such as your preferred difficulty, activated zone if there were any that was decided by the therapist, finished time and username. In this scene the player can choose to play again or return to main menu. This scene also contains a script which sends your current game information to our MongoDB using fastAPI and to access previous reports, you must be logged in as a therapist and enter the report number input you want to see, which displays the report with the corresponding report number.

We receive data from the player about the game, such as the time to finish the game for games with different settings, a coordinate matrix where we can analyze the regions where he spends more time on the board. In this way, we can interpret the aspects that the patient focuses more on and needs to be developed through the heat map. The acquired real time data contains the username of the child, preferred difficulty, score, finished time and the coordinates which the player has travelled.

After building the database, we needed to connect it. To do so, we decided to use an API to connect to Unity, to do this we have created a backend with python and a FastAPI structure, with this structure we have connected to Unity. In this way, when we enter the report number using the API, we are able to access the report we want in the database. In doing so, we were able to publish a report at the end that appeared with the Game Over screen, which recorded the time and the set difficulty of the level, which was then sent to the database and saved. This was our objective.

After analysis, we want to report the score, finished time, the corresponding level and preferred difficulty, as an indicator of how well the player has performed. In addition, we implemented a heat map which is created by the coordinates player has travelled during the game, with the destination target's position, to see whether the player has a challenge to move towards certain points which can give feedback to work on those areas are more important.

We present these findings in a report page where these reports are only accessible by an admin phrase, after this phrase has been entered, the therapist is then taken to a page where he/she will enter the username of the patient and following that the report number they want to see and gain information about. Firstly, we wanted to display this overall report

structure using html, however due to html being not sufficient with the dynamic changes that may occur while a therapist is using these pages, we have decided to relocate this part of project to react environment. Which enables us to represent our report and findings in a better way. In the report page, findings are represented as follows; the image of heatmap created by the real-time coordination data of a player's traversals during a level, the corresponding time, preferred difficulty and region zone and finally the score which is corresponding to the collectables the player has collected while playing the level.

Finally, construction of reports for each session of a played level by the user delivered what is expected, as we present the collected data in a clear and meaningful way which is both easy to understand as well as informative. Regards to our data deduction many meaningful data is possible and in our reports page we have tried to explain what kind of information can be gained from the parameters as clear as possible.

4. RESULTS & DISCUSSION

Our goal was clear but a bit trickier to implement. As a team of 3, as evident from our previous reports, we have changed a lot of details but the core and the goal of the project stayed the same.

As we wanted, we generate a report based on performances. We display this report intelligibly and easily. The use of the menu and tools is intuitive and easy, which makes it accessible. The game is simple to understand and not hard to play. We really didn't want to discourage the children so default difficulty and difficulty adjustment were handled with care.

As of right now, the game is complete mechanically but incomplete aesthetically. We want the character to be an armadillo but it was really hard to find a 3D model of that, so one of us is currently working on it with Blender which is not an easy software to learn. We cared

so deeply and worked so hard for the core objective of the project. When the aesthetic elements are also completed, this will greatly increase the charm of the game.

In our research, as stated previously, we recruited the help of a friend for music and sounds. It is important for us that our game is a game that children could want to play. We also cared about this when we came up with the jungle theme. We wanted to make a unisex game that all small children could enjoy.

Initially, we thought we could implement an AI that would adjust the difficulty of the project depending on the child's performance but we scrapped that idea and this was not implemented. This was the only thing we did not implement from our Proposal.

In conclusion, our game is finished except for finishing aesthetic touches. All of our initial objectives have been realized. We wanted to be able present data that we were able to collect and do it understandably, which we've done. We wanted to allow the therapist to make some adjustments with respect to their insight and information about the child which would impact and personalize the experience of the child, which we've done. We wanted to have a database that housed all reports and was able to generate an overall progress report specific to the child, which we have also accomplished. We wanted to make a game that was fun, unisex, easy to play, utilized positive reinforcement, colorful, and with fun music and sounds which we believe we have also done. We wanted to help the balance training of children with CP and every therapist we talked to loved the concept of our game and wanted to see it done!

All out objectives were set with academic and market research, the expertise of our supervisor, and the inputs and directions of therapists. We hope our contribution to serious games for children with Cerebral Palsy is found to be useful and manages aid many a child and therapist.

5. IMPACT

The most meaningful part about this project is of course being able to help children. This game will be donated to Türkiye Spastik Çocuklar Vakfı. In many cases of computer science, the meaning is in innovation and technology. But in our project, the meaning mostly comes from usefulness. In this area, the more useful the games are, the better. Children are easily bored as much as they are easily entertained, and the prospect of being able to aid a child's therapy along with providing them entertainment is what this project gets its meaning from. Accessibility and usefulness are the keys to this project as well as transparency and data. We are really proud to have done such a project that can actually be useful. We are hoping that the children will enjoy and improve with our game and that therapists will find our game useful.

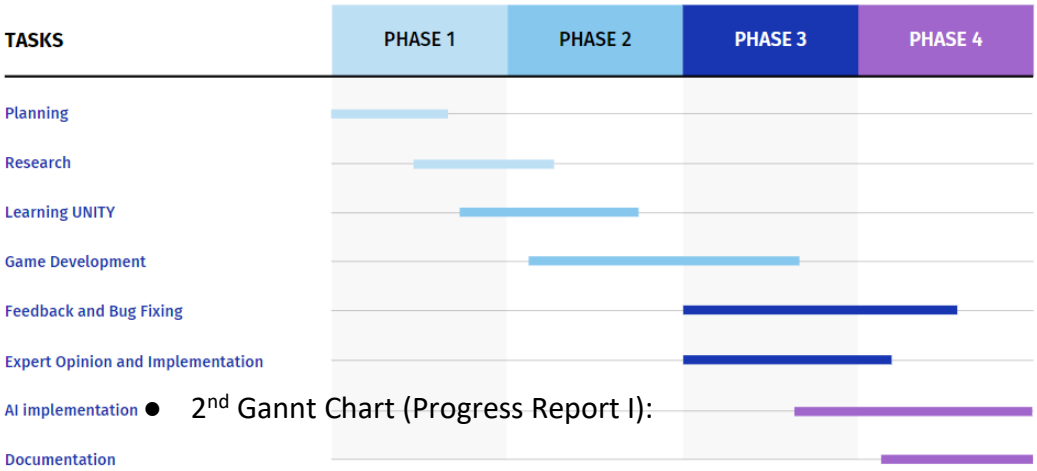
Since all this game requires a Wii Board and a computer, the music and sounds are done specifically for this game, and all assets used are free online sources, there are no Freedom-to-Use (FTU) issues as accessibility was an important aspect for the game.

6. ETHICAL ISSUES

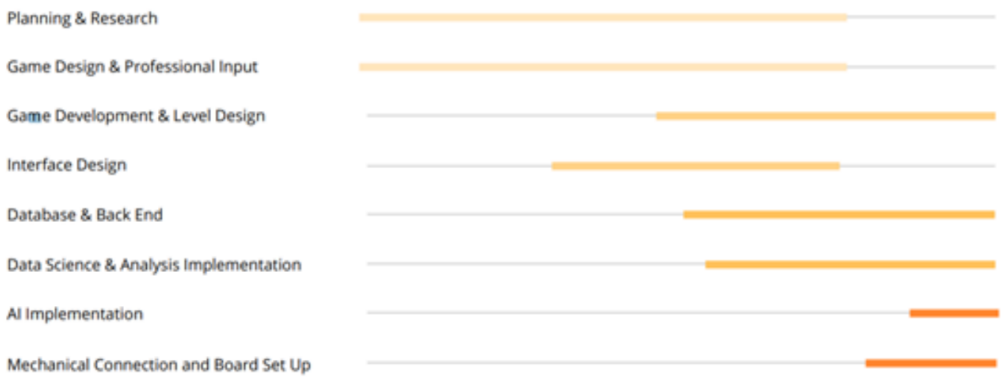
Since the practical use of this project is to be done under strict therapist or parental supervision, we don't foresee any ethical issues as this is the nature of serious games that are used in physical therapy.

7. PROJECT MANAGEMENT

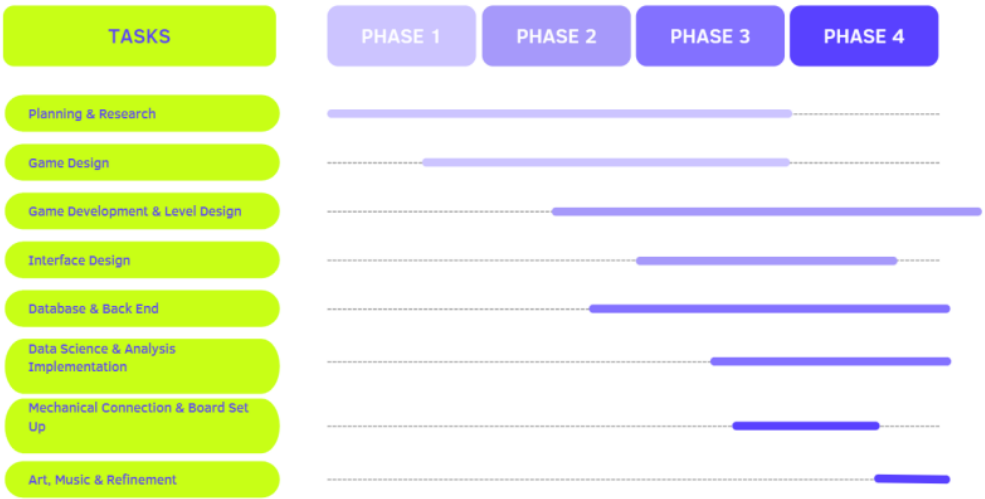
- 1st Gannt Chart (Draft Proposal & Project Proposal):



- 2nd Gannt Chart (Progress Report I):



- 3rd Gannt Chart (Progress Report II):



The project was really hard to juggle as senior students. We had meetings and used Discord and WhatsApp as our communication and we were always aware of what each of us was doing.

It was useful for us to have made the Gannt charts using phases rather than actual dates because our exam dates, homework dates, quizzes, other projects etc. were unpredictable.

As visible above, our understanding of time management and project planning has changed as we worked on this project. We had severely underestimated the data science part of the project as well as refinement. Transitioning data from Unity to a database was harder than we thought it would be because of unforeseen problems about the way Unity and C# worked. Refinement is/was hard because of limited resources since we use free assets available online. We are hoping to refine the UI that is present during the game as well as find/construct a 3D model for our character which was not available online, not even in paid products, which we hadn't foreseen.

8. CONCLUSION AND FUTURE WORK

We will receive feedback on our project's latest iteration from a therapist very soon. That will be very beneficial for our project and we are looking forward to implementing any last changes that might be needed.

Our biggest benefit was having access to professionals working in the field. The feedback of a therapist, especially during the design phase taught us what was needed, what was important, and what could be most beneficial.

Naturally, the most important feedback will be when the product is used and tested by children and therapists. Currently, the biggest drawback of our project is the lack of testing. This was only natural since we couldn't have had children with CP test our game. We look forward to its reception and feedback very soon.

The next step for the project is to complete the refinements, meet with our supervisor and therapist and test the game.

If the work on this project could continue, it could be very beneficial to increase levels, bring some more customizability both aesthetically (playable character customization, background customization etc.) or more difficulty adjustment (change the location of the cave, change location of start point etc.), create more unique levels if there was a therapist available that could be worked very closely with, and implement that AI that was discussed in the Proposal phase that we have decided to scrap. These would increase the replayability of the game.

9. APPENDIX

- https://drive.google.com/drive/folders/1d2c9zbaZW04sONfaZudG6JMaF2ghM7as?usp=sharing

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