DEVELOPING AN INCLUSIVE TENNIS SIMULATION GAME: ENHANCING PHYSICAL ENGAGEMENT AND SOCIAL SKILLS FOR CHILDREN WITH AUTISM THROUGH ADAPTIVE AI AND REALISTIC GAMEPLAY EXPERIENCES

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ABSTRACT

During the long-term process of doing this tennis project, I had created and added many different features into the game, including different types of game modes, competitive tournament map, and music and sounds. One of the most significant features is the AI opponent with three different levels of difficulties for all the three game modes [1]. I designed these three game modes because of the challenges that I faced when I was trying to teach and communicate with children with autism, and that I think it might be a good idea for them to enjoy and relax themselves [2]. My idea of this project appeared in my mind after I was done with my volunteering event, I really wanted to help them out because of the situations that they are having in their lives. From the experiment that I did, I did find some inaccuracy of the swings in the game because sometimes when I swing my arm in front of the camera, the pose estimation didn't really capture it. However, the data that I collected in this experiment tells me that I just need a little improvement on the calculations of the motion capturing system. People should start to try playing my game, especially the kids with autism, because the game could be played through a projector which allows the kids to experience the realism of the game of tennis and it builds up important social skills for them and provides a bunch of benefits to their lives [3]. This project is a game that could slowly help them to build up a better understanding for them about the game of tennis, which could bring benefits to their physical health while having fun playing the tennis mini games.

KEYWORDS

Autism-Friendly Gaming, Adaptive AI Opponents, Physical Engagement, SocialSkill Development

1. INTRODUCTION

This program about playing tennis that I made was mainly inspired by the one volunteering event, which was to teach the kids that have autism to play tennis at my school. At first I thought it would be an easy job to walk the kids, however, when I actually got on the court I found out that they couldn't listen to anything and they just live their lives in their own worlds. When I tried to

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communicate with them, they couldn't understand a single thing that I said to them because of all the distractions around them. They sometimes get distracted by a small butterfly that flies past or the new environment around them that they wanted to run around on the court. During the time teaching them about tennis, sometimes they will be lazy and give up when doing the drills because the drills were somewhat hard for them to participate in. Then they will sit on the ground or go to find their parents to take a break and I could not really persuade them to get back to practice because of their lack of communication and social skills [4]. This problem that I faced ultimately led to the idea in my mind to support and help out children with autism, and provide them with a skill that they could build up their social skills and a sport that they are able to participate in.

In the first of the three methodologies, it talks about how football can help children with autism in several ways, for example social skills and communication through collaboration while playing this sport. However, the shortcoming of this methodology is that a lot of children with autism don't have the basic social and communication skills, so they couldn't even collaborate with each other because of this issue. The second methodology says that swimming is the one of the best ways to support children with autism because it builds endurance heart rate, and it has also shown to improve motor skills [5]. However, the shortcoming is that some autistic kids might be afraid of getting into the water because it might be a new kind of environment to them, which could cause this solution not to work because of their fear of getting into the water. The final methodology describes how the sport of biking could bring benefits to the autistic kids because it could help them to develop a strong body awareness, and they can participate in groups or individuals. However, this would not be working very well because again it might be a new thing for them to learn and it might be very dangerous for the children with autism that don't really know how to ride a bike. In conclusion, my project is an improvement over those methodologies for the reason that it is a motion-tracking game that doesn't require the children to go outside or even buy any equipment. It is also safe for them to participate in because they could just play tennis at their home. All of the three methodologies can't not be done through a screen or a projector, which my tennis game project could be easily played through a project (for best experience) by the children with autism [6].

This Tennis Game is a pose estimated and interactive app to help children with autism to develop focus and social skills through a virtual tennis game. It is also a game that could be played through several ways, for example through a computer screen, TV screen, projector, and etc. This game tracks and analyzes player's movements by using the pose estimation tool, which allows kids to play this video game without using physical equipment. This game also offers tennis challenges with an AI opponent to help the players to improve their accuracy and reaction time [7]. This solves the problems with the kids that have autism because children with autism often struggle with social interactions, coordination, and long-term focus. This tennis game could help them to develop these skills. This game is unique compared to other video games because it uses the tool pose-estimation as a guideline, which could help the children with their actions and postures. Another reason is that this app allows for customization based on each child's abilities and preferences. It can adjust the difficulties between easy, medium, and hard. This game is more effective because it contains the engagement from the sport of tennis and it also encourages kids to work through challenges while playing against a hard AI character. This game can be played by using a projector for better in-game overall experience, which could prove players a better view of the tennis court and give a realistic in life tennis playing.

Overall in this project, the three main factors in the game will bring players satisfied experiences and gameplay, which are the three most significant features: AI system, pose estimate, and game modes. I did a total of three experiments on the three different features; I did calculations and testing for the accuracy of the AI opponent in the game, I tested the pose estimate system by

using my own projector and by finding the camera captures that it missed, and lastly I did experiment on the three different game modes, which was just to test out each of the game modes for running smoothly and correctly. For each of the three experiments that I did, I actually recorded the data from the testing and I found out that each of the sections is working pretty well and each of their success percentages were above 85%. My experiment was pretty successful to me because I had an opportunity to adjust my game and have a look at whether all the features function right or not.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Post Estimate

Sample Skeptical Question: How does pose estimate affect the player's overall experience when playing the game?

Sample Response: The special tool pose estimate that was used inside of the game allows players to use their arms and bodies instead of using actual objects physically, for example a mouse or a controller, which could decrease the player's overall enjoyment for the game. The pose estimate could also bring a realistic picture and experience to the players that wanted to have a touch with tennis or even learn about it. In conclusion, pose estimation in this game could bring mostly positive experience for the users that will be playing this game because of its special gameplay in the game and the realism element while playing it.

2.2. Swinging Animation

Sample Skeptical Question: How does swinging animation work in the game?

Sample Response: Swinging animation is another huge element inside of the game, which is captured by pose estimation whenever the players swing their arms [14]. One of the reasons why swinging animation is one of the most important features in the game is that it is also the most significant part in playing tennis. While in the game, players have to swing their arms just like playing actual tennis in front of their computers' cameras in order to allow pose estimates to capture the swings, which the swing will immediately transfer to the character in the game. However, this game has not yet created the left arm swing yet. This feature will be added in the future.

2.3. AI

Sample Skeptical Question: Why is this the most important feature in this game?

Sample Response: AI in this game is used as the opponent for the players for all different mini games. AI is the most important part of the features in this game because it allows players to actually play against an opponent that is good and skillful, which could provide players challenges and enjoyments while playing through those challenges [15]. Another reason why is that the AI opponent contains three different levels: easy, medium, and hard. Easy AI which is the easiest one to play against, the medium AI sometimes could be really tough to play against, and lastly the hard AI which has the increased speed while moving and increased swinging pace.

3. SOLUTION

When the Tennis Game is loaded you will then see the three options on the main menu: Settings, Play, and Quit. Settings are basically for all of the volume controls, it contains master, UI, music, and SFX, you could adjust the music and sounds that you want in the game. For the second option Play you will launch to another menu that has different game modes and the difficulty of each game mode. For the game modes it contains following, reflex, and rally, and each game has three levels of difficulties: easy, medium, or hard when you play against the AI (you will not play against different players because it is a singular player game). In the first game mode following, the player has to follow the ball wherever the AI hits, and if the player successfully touches the ball, then the player will receive one point. For the second game mode reflex, the player has to hit the ball successfully that the AI hits to you by swinging your racket, and the player will not be able to move around. For the last game mode rally, it is basically the combination of the following and reflex: the player has to both move and hit the ball successfully wherever the AI hits. The AI will change its moving and hitting speed based on the difficulty that you chose to play for this game mode. Lastly, the last option Quit is to just exit the game whenever you are done playing this fun tennis game!

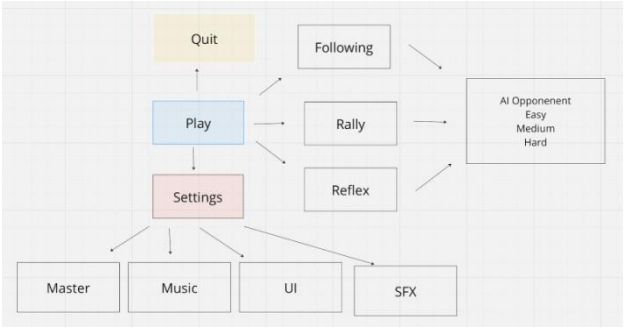

Figure 1. Overview of the solution

This tennis game that contains three different mini games is based on pose estimation, in which all the players are required to have cameras on and placed somewhere properly to have full body player view. The camera captures players' movements and their swings to simulate the motions that the character in the game will receive.

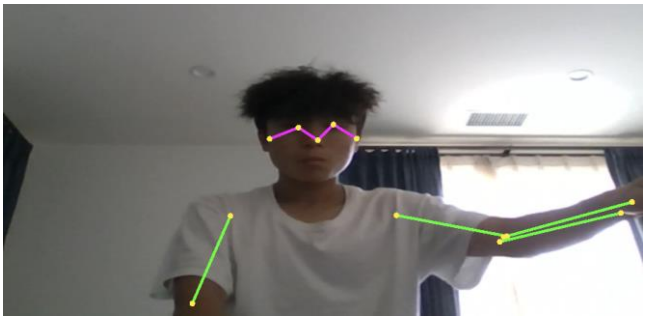

Figure 2. Screenshot of the pose

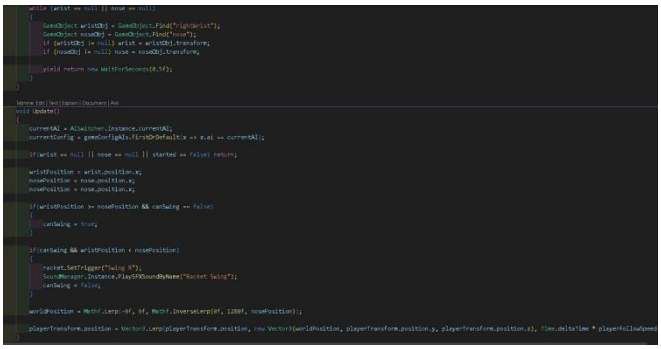

Figure 3. Screenshot of code 1

The game uses a pose estimation AI package that we can use to identify parts of our body and its movements [8]. This package mainly uses the Pose Estimator script that manages all this identification and tracking. The script spawns visual "bones" through our camera that effectively follows different body parts in our inspector. Each bone is labeled accordingly and neatly which we use to identify the bones we need to keep track of during gameplay. In each mini game script, we look for a specific bone(s) to do certain tasks at the start of the game by looking for the name in the inspector. In the rally mini game for example, we look for the game objects named "rightWrist" and "nose. The rally mini game needs us to move left and right and swing our racket. To move left and right we simply take the x position of our nose and translate towards our player's x position. For swinging our racket, we simply check if our right wrist x position is less than the nose's x position which tells us that our right hand has made a right to left swing across the body indicating a racket swing.

Another important component of the game is the AI. The game consists of different difficulties, so before we start moving the AI, we have to configure it differently for different mini games and different difficulties of our choice. The config mainly affects how the tennis ball behaves during gameplay.

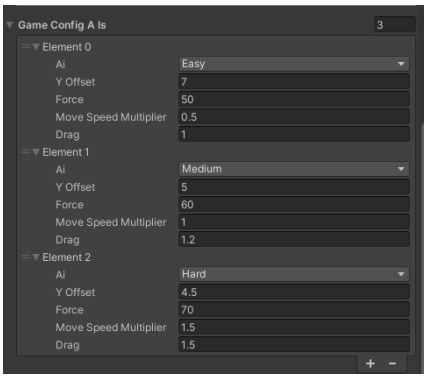

Figure 4. Screenshot of the game config

```
public List<GameConfigurationAI> gameConfigAIs = new List<GameConfigurationAI>();
[ReadOnly] public GameConfigurationAI currentConfig;

AISwitcher.AI currentAI;

[Serializable]
public class GameConfigurationAI
{
    public AISwitcher.AI ai;
    public float yOffset = 6;
    public float force = 70;
    public float moveSpeedMultiplier = 1;
    public float drag;
}
```

Figure 5. Screenshot of code 2

The GameConfigurationAI class mainly allows us to store different values that controls how the ball will behave. Each mini game contains their own list of gameConfigsAIs, which at this current moment, all have 3 elements. Each element has a unique AISwitcher.AI (Easy, Medium Hard). For whatever AI (or difficulty) the player choses, the corresponding GameConfigurationAI values are used during gameplay. The class, more specifically the Rally mini game, contains 4 floats variables. yOffset is a y position offset for how high to hit the ball from the AI's hand. Force is the impulse force added to the rigid body when the ball is hit by the AI. moveSpeedMultiplier is used for how fast the AI character moves side to side. And lastly, drag which changes the Rigidbody's drag component value. Different mini games vary in values for each difficulty as for example games like reflex need a faster ball but still be able to get our player head down. While a game like the following requires a less fast ball and still bounce on our side at least once.

Another important component is the AI Controller [10]. The AI is your opponent for all mini games and will need to do different tasks for each one. The AI is composed of different functions to make it function in any kind of mini games we have and the animations it needs to look appealing.

Figure 6. Screenshot of the game

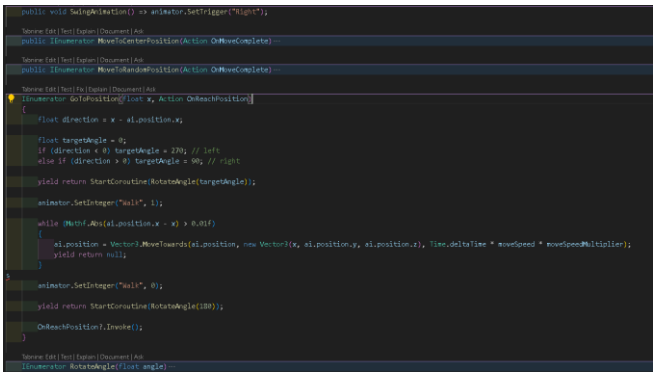

Figure 7. Screenshot of code 3

The AI's movement revolves around one single coroutine, the "GoToPosition" coroutine. This coroutine takes in an x which is the x target position it will go towards and an Action type delegate that can store any function and runs them whenever the position target is reached by the AI. This coroutine consists of three parts, first rotate towards the direction it wants to go, start walking towards that direction till it reaches the x target positions and then rotate back forward towards us. This coroutine is mainly used on the MoveToRandomPosition coroutine which is what is used by all the mini game scripts. Having the AI move to random positions allows a variety of incoming shots from the AI which simulates our training. After the x target position is reached and the Action delegate is called, all mini game scripts just runs the SwingAnimation functions which runs the AI's animator trigger for swinging the racket. Which all effectively completes a successful AI swing.

4. EXPERIMENT

My game does contain AI systems in my program, which I tested out the AI component's accuracy [9]. This is important because sometimes if the code for the AI program is a little bit off, it could affect the way that the character hits the ball and the place that the ball he is hitting to.

For testing the accuracy of the pose estimation in the game that captures each player's swings, I did 20 inputs that I had to swing my arm 20 times and see how many times did the pose estimate system actually capture. In my hypothesis, I thought the pose estimate system would be able to capture every swing that I do, however, after the experiment it only captured 16/20 swings, which shows the inaccuracy of the pose estimation system. It is important to record my input responses like this because it allows me to see and examine the problems that the AI system contains, which could provide me the chance to optimize the game.

PER SWING	HIT ACCURACY
Swing 1	True
Swing 2	True
Swing 3	True
Swing 4	True
Swing 5	True
Swing 6	False
Swing 7	True
Swing 8	True
Swing 9	True
Swing 10	False
Swing 11	True
Swing 12	True
Swing 13	False
Swing 14	True
Swing 15	True
Swing 16	False
Swing 17	True
Swing 18	True
Swing 19	True
Swing 20	True

Figure 8. Table of the experiment

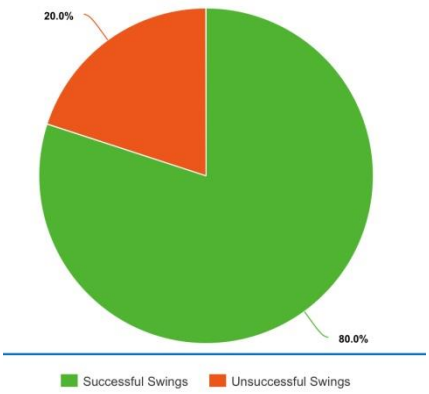

Figure 9. Figure of the experiment

So based on the experiment that I did on my pose estimation system, out of 20 swings there were 4 swings that didn't get captured by the pose estimate system, which is about 20% of the swings that didn't show inside of the game. This unsuccessful swing percentage is bad news to my project because it could eventually bring bad experiences for the players who are playing the game. I actually found the pattern of missed swings; the pose estimate system didn't capture the swing after four to five swings. This result concluded that some of the inaccuracy of the motion capturing system could affect the in game experience. However, this could cause several other reasons, for example, the miscapture from the camera, the player going out of the picture frame

of the camera, or even computer's internet issues. The incomplete swings in the game could actually be caused by a lot of reasons. This data from the experiment is just the basic overview and rating for the pose estimation system.

5. RELATED WORK

Football as an Alternative to Work on the Development of Social Skills in Children with Autism Spectrum Disorder with Level 1 by Jose Maria Lopez- Diaz, NerraFelgueras Custodio, and Inmaculada Garrote Camarena [11]. This research paper is basically saying that playing football could help the kids with autism to develop their communication and social skills through collaboration. This research paper is different from mine because my project is based on playing tennis and not really through collaboration by participating in a team sport. The similarity is that both of the research projects are using sports to help the kids with autism kids to develop social skills. However, they have to play football at an actual field and maybe experience physical contact with each other, and because of the social issues that they have they might have a little trouble communicating with others. In my opinion, my tennis project is better because of the use of optimized technology and that children with autism could learn a new sport through a new way that they never thought about before, and the game is often played with a projector because it could provide a best overall experience in the game of tennis.

Benefits of Sports for Children with Autism is an article written by the company Helping Hands Family, which it writes about how swimming could provide benefits to the autistic children because it builds endurance heart rate without the negative impact of stress and it has also shown to improve motor skills in children with autism [12]. This research project is different from mine because this one the kids have to actually get into the water and physically try to exercise, on the other hand, my project doesn't really require them to go somewhere else. These two projects are pretty similar because they are both using the way of doing sport to support the children. However, my project is a fictional sport, which means that they don't have to actually play tennis outside, they can just play tennis in front of the projector and learn tennis throughout the screen. In my opinion, my project is slightly better, for the reason that they might be out of control when they are in the water because of the new environment or surroundings that they are experiencing, whereas my project doesn't require them to leave their house and they could still learn tennis through the a projector in their houses.

Total Education Solutionsis a research article that talks about the best sports for the kids with autism to participate in, which it describes as a great way for the children to stay active and enjoy the outdoors [13]. It also talks about how this sport is a low-impact, high endurance recreational activity that can be done individually or in a group, and it also plays a major role in helping the kids with autism to develop a strong sense of body awareness and control. My project is very similar to this one because both of the projects are singular only sports, which means that those two don't require any social interactions. However, the part that is different is that biking requires the children to know how to actually ride a bike, and my project only requires the children to stand in front of a projector or a camera or a screen to experience the game of tennis, which doesn't really require a lot of skill. In my opinion, my tennis project is still a little better because it could prevent children from getting injured while riding their bikes.

6. CONCLUSIONS

Talking about my project, the tennis game does have a lot of limitations even though it has three different game modes to play on. The biggest limitation in the game would be the players are only allowed to move from left to right, and not moving forward and backward. This limitation

brings down the player's freedom of moving around on the court in the game. Another limitation in the game would be the limits on game features, which means that the game does not contain any store for buying new characters or upgrading the racket because it is a very classical tennis game. If I was given more time to work on this project, I would absolutely add voice messages for the characters and another game mode for competition, which means that players have to play an actual tennis match with the standard time length and rules. I would like to expand my program in the future by doing more research about the children with autism and getting to know better about what their personalities are like and what are the activities that they like to do. If I was to start over this project I would consider creating a larger map and add more features into the game which could provide players and children with autism more opportunities to interact with this tennis game.

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