AN ENTERTAINING APPLICATION TO MIX EXERCISE WITH FUN USING POSE ESTIMATE AND UNITY

Alexander Wu[1], Amelia Wu[2], Moddwyn Andaya[3]

[1]California Connections Academy Central Valley, 580 N. Wilma Ave., Ste. G, Ripon, CA 95366
[2]Human Biology Department, UC San Diego,9500 Gilman Drive, La Jolla, CA 92093
[3]Computer ScienceDepartment, California State Polytechnic University, Pomona, CA 91768

ABSTRACT

We address the rising issue of increasing weight and declining health due to sedentary lifestyles and unhealthy diets. Our solution involves a camera tracking system that monitors users' movements and offers six engaging exercise games, bridging the gap between fitness and enjoyment. The project comprises three interconnected components: pose estimation, game information, and mini-games, with C# code utilized for pose estimation and individualized coding for seamless integration of each game.Throughout the development process, three notable challenges emerged: occasional sensory issues with the pose estimate, animation complexities, and the absence of an effective scoring system. To enhance the efficiency of the pose estimate, we conducted three rounds of trials, each consisting of ten arm circles, revealing that proximity to sensors was a common cause of issues.The animation challenge was overcome by incorporating free, simple, and readily available animations from online sources into human models for games requiring user interaction with models. To address the scoring dilemma, we clarified game goals by providing text instructions, guiding users on how to achieve success.This application caters to a younger audience, offering affordability, visual appeal, intense exercise, and swift results. Balancing fitness and fun, it presents an ideal solution for those seeking an engaging and effective exercise regimen.

KEYWORDS

Exercise, AI, Unity, Mini Games

1. INTRODUCTION

In recent years, a growing number of individuals have experienced an increase in average weight, attributed to unhealthy lifestyles and a burgeoning addiction to the captivating allure of video games. This addiction often manifests as a preference for prolonged periods of sedentary gaming, where individuals remain in a fixed position for extended durations, significantly reducing overall physical activity. This tendency, when combined with excessive video gaming, can lead to severe mental and physical consequences, some of which may prove life-threatening. The consequences of extended periods of sedentary behavior are well-documented, with associations to various diseases and ailments such as diabetes, heart disease, and obesity [1]. Prolonged sitting can contribute to muscle atrophy, bone weakening, and diminished circulatory system performance,

David C. Wyld et al. (Eds): IoTE, CNDC, ACITY, DPPR, AIAA, NLPTA, WEST, ICSS -2023
pp. 77-86, 2023. CS & IT - CSCP 2023 DOI: 10.5121/csit.2023.132206

affecting blood flow [8]. A study conducted in 2002 highlighted that among 1,480 individuals with type 2 diabetes, 31% reported no physical activity, while an additional 38% engaged in activity below recommended levels [2].Evidence suggests that prolonged periods of inactivity increase the risk of chronic diseases, with a mere two-hour increment in sedentary behavior raising the likelihood of obesity by 5% and diabetes by a significant 7% [6]. Alarming trends indicate a surge in national obesity rates, rising from 13% in the early 1960s to approximately 43% in recent times [3]. On a global scale, people spend an average of 6 hours and 58 minutes daily on digital screens, with excessive gaming linked to heightened cardiometabolic risk, disrupted sleep patterns, and unhealthy eating habits in youth [4][5]. Mental health is not spared, as individuals may exhibit symptoms such as unhealthy coping mechanisms, declining academic performance, diminished self-esteem, social isolation, and a pessimistic mindset [7].

The intricate interplay between sedentary behavior, video game addiction, and associated health risks underscores the urgency of addressing these issues to foster holistic well-being.

In October of 2021, a study was done involving Kinect Adventures for type 1 diabetics, and though the solution that they utilized was very similar to what we did, Kinect Adventures relied on lots of potentially expensive equipment, while our project was more affordable and could be played on a computer. Studies that involved Pokemon Go showed that players were generally more physically active and walked for much longer distances. Although Pokemon Go is beneficial for encouraging longer and healthier walks, our solution provides more intense exercises over a shorter period of time, and health benefits will become apparent much sooner. Lastly, studies on Dance Dance Revolution provided results that suggested that adults who familiarize themselves with exercise were able to achieve at least 8.0 in the METs system, and the game was also tested on kids with health risks. While their solution had results similar to ours, the study did not cover aspects such as motivation, and Dance Dance Revolution itself is way too vibrant, complex, and potentially disorienting for younger audiences to properly comprehend. On the other hand, the solution that we have is more specialized towards kids and teenagers, with a simpler design along with game styles that more easily resonate with them.

To solve the problem at hand, we are proposing a game that encourages exercise in order to play successfully. The software will have six different mini games that players can choose to select from. Each mini game will have a video that shows a preview of gameplay to show the users what they are doing.Along with a preview of what the game looks like, there is also an animation that shows how the chosen mini game's particular exercise is meant to be performed. Cameras and sensors will record how the user moves during the mini game. At the same time, AI will estimate the pose of the user and use the information to determine whether to move or act within the mini game. To give users a goal to aim for, the games have a timer, which will prompt players to try to either survive as long as possible, or win as fast as they can. The game that we are creating will be able to solve the issue at hand by creating more exercise for the targeted audience through the gamification of relatively simple simple exercise activities. This solution will be highly effective at its purpose, since it simulates the feelings of intense motivation people feel similar to that which many people go through while playing video games. Consequently, it prevents a sedentary lifestyle by creating a feeling of competitiveness and motivation to continue to play the game's exercises in order to achieve that feeling of "winning" the game.

To test the possible faults of our pose estimate's ability to detect the movements of players, we set up an experiment in which we tested its functionality multiple times to analyze its accuracy, and recorded the data based on our observations. Our priority was to find which of the factors caused the most frequent complications and work to resolve that factor first. After that, we then moved on to the other factors and adjusted them next to make sure that our project was in working order. Something significant that we noticed in our findings once our testing was over was that out of three trials of ten arm circles, the second trial had an outlier value of four arm circles that were detected, while the first and third trials were Two reasons that this occurred was likely due to being too fast for the sensor to properly sense our actions, or that we were too close, which inhibited the sensor's line of sight.

2. CHALLENGES

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

2.1. The Camera or Sensor

The game that we are creating will rely heavily on detecting exercises that players must perform in order to play the game. An issue that may surface is the camera or sensor not properly perceiving movement and consequently not making the character within the game act, disrupting a sense of flow and causing users to be reasonably displeased. Our solution will be to test the functionality of the pose estimate used multiple times in separate trials, and then negate whatever factors managed to disrupt the sensor and cause the fault, such as potentially dim lighting, or moving any objects out of sight.

2.2. Animating both models within the games

Another major setback that we may face is adequately animating both models within the games, and exercise pose animations as demonstrations for each of the games. The engagement that users will feel when playing certain games is highly reliant on animations that match what the player must do.The animations must also be smooth enough to fit in with the scenery, while not complex enough to confuse the user.In order to circumvent the time-consuming nature of manually creating animations, we will search the online web for free to use animations that are simple but straightforward, and import them into human models for each game that relies on the user seeing any of the models.

2.3. Score the performance

Lastly, a third concern that we have is that we may not know how to adequately score the performance of a user, as some of the games have conditions for victory that contradict each other, such as a game where the player has to survive as long as possible, along with games that require doing a certain action as fast as possible to win. Having many different types of goals could confuse the player, frustrating them.We could come to a middle ground by clarifying what the goal of each game is meant to be through providing text instructions. They would appear before the game starts, in order to guide the user on how to win.

3. SOLUTION

Our Unity-based game, developed with C# code, comprises three essential components: the pose estimate, game information, and mini-games. When users access the application, the experience begins by guiding them to the game selection interface, offering a variety of mini-games. Given that the list of games exceeds the screen's initial display capacity, users can easily scroll left or right to explore all available options.Upon selecting a game, users are presented with a comprehensive description, incorporating visual footage showcasing the gameplay, associated exercises, and the lore within the chosen game. Each game video features brief gameplay snippets, complemented by separate videos demonstrating the corresponding exercises. Once users hit the play button, they are seamlessly transitioned to the game interface. Here, visual exercise instructions reinforce proper techniques, accompanied by text instructions for each exercise. Initiating gameplay is as simple as pressing the play button when ready.Upon completing each game, a game-over screen prompts users to either exit and return to the game selection or try the game again. Positioned at the center of the screen, users can easily view their current highest score achieved during the gameplay session. This user-friendly interface ensures an engaging and informative experience, encouraging users to track their progress and stay motivated.

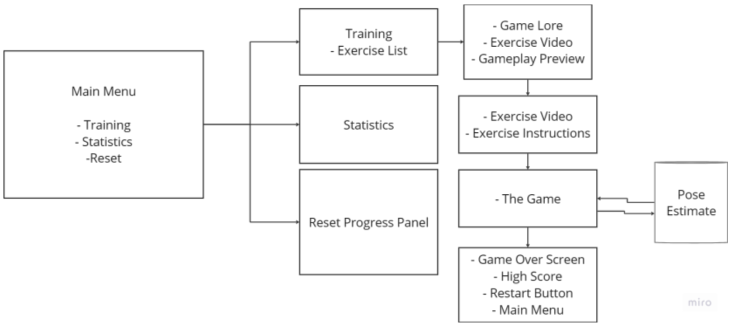

Figure 1. Overview of the solution

The game descriptions require many fields information to show and be used on UI display for each specific exercise. Each information about a specific exercise is stored as a scriptable object in the project's folder. Each of these objects contain information about the exercise's name, description, video, icon, scenes, and other data storage.

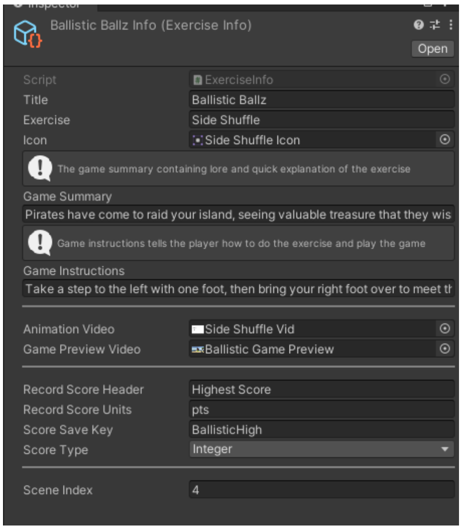

Figure 2. Screenshot of the project

```
using System.Collections;
using System.Collections.Generic;
using NaughtyAttributes;
using UnityEngine;
using UnityEngine.Video;

[CreateAssetMenu(fileName = "Exercise Info", menuName = "Fit For Fun/Exercise Info", order = 0)]
public class ExerciseInfo : ScriptableObject
{
    public string title;
    public string exercise;
    public Sprite icon;

    [InfoBox("The game summary containing lore and quick explanation of the exercise")]
    [ResizableTextArea]
    public string gameSummary;

    [InfoBox("Game instructions tells the player how to do the exercise and play the game")]
    [ResizableTextArea]
    public string gameInstructions;

    [HorizontalLine]
    public VideoClip animationVideo;
    public VideoClip gamePreviewVideo;

    [HorizontalLine]
    public string recordScoreHeader = "Highest Score";
    public string recordScoreUnits = "pts";
    public string scoreSaveKey;
    public ScoreType scoreType;

    [HorizontalLine]
    public int sceneIndex;

    public enum ScoreType{ Integer, Float };
}
```

Figure 3. Screenshot of code 1

The code inherits from ScriptableObject and has a CreateAssetMenu attribute which works together to allow us to create this class as an object on our project's folder. There are a lot of fields that store information about a specific exercise here. We have the basic fields such as the title, exercise, and icon which are used for the main menu's exercise list. The video clips store the video animation of the exercise and a video preview of the mini game. Along with the videos are also the game summary and instructions which are the text instruction alternative to the video. And we also have other data fields relating to the score saving of that specific exercise. We store the "key" used for PlayerPrefs saving that the type of score it is (a whole or decimal number). And we also store the header and units which are used for UI score formatting.

There are 6 mini games in the whole project and each contains their own logic of code. Each mini game is represented as an exercise with each of their own instances of the post estimate. Each mini game tracks your body in a specific way that resembles the given exercise to control the mini game.

Figure 4. Screenshot of mini game

```csharp
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class BoulderBladeSword : MonoBehaviour
{
    public BoxCollider checkCollider;
    public Animator anim;
    public void Slice()
    {
        BoulderBladeManager.Instance.player.OnSwing?.Invoke();
        foreach (Collider boulder in GetCollidersWithTag(checkCollider, "Boulder"))
        {
            boulder.GetComponent<Boulder>().Break(false);
        }
    }

    Collider[] GetCollidersWithTag(BoxCollider collider, string tag)
    {
        Bounds colliderBounds = collider.bounds;
        Collider[] collidersInsideBox = Physics.OverlapBox(colliderBounds.center, colliderBounds.extents);

        List<Collider> collidersWithTag = new List<Collider>();

        foreach (Collider col in collidersInsideBox)
        {
            if (col.CompareTag(tag))
            {
                collidersWithTag.Add(col);
            }
        }

        return collidersWithTag.ToArray();
    }


}
```

Figure 5. Screenshot of code 2

Choosing from one of the mini games in the project, Boulder Blade, we can look at its components to how the game functions all together. The game's goal is slicing up an incoming landslide of rocks by swinging your swords forward. Now aside from post estimate control (for now), this code controls how the sword in this game functions. We have a Slice() function that is called during the slice animation of the sword. The function will call an action of OnSwing that will run other external features of the swords that we desire to customize later. But it will also check inside the sword's collider if there are any other colliders that have the tag "Boulder" and if it does, we will have access to that boulder we hit and call its Break() function. The Break() function will have its own implementations like destroying the boulder and other minimal features like spawning particles.

The most important component of the project is the post estimate. This is what controls the player of the game that allows you to not only win the game but also provide the goal of the application which is to promote physical movement and exercise. The post estimate captures your body movements through your camera.

Figure 6. Screenshot of captures

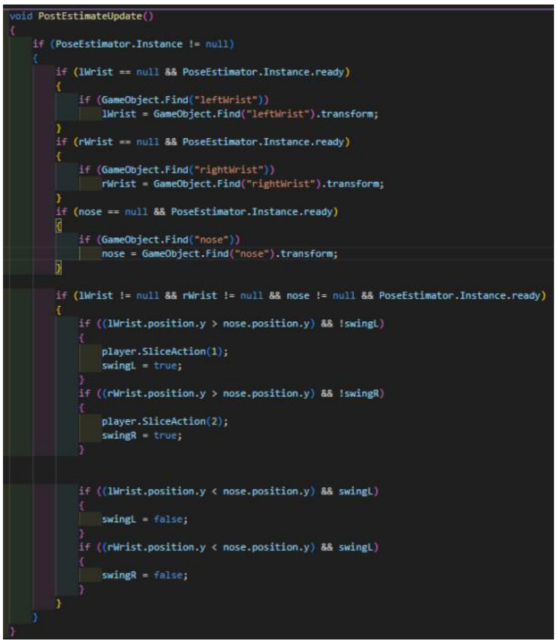

Figure 7. Screenshot of code 3

The post estimate, at the start of the game, and if your camera is accessible and parts of your body are exposed, will spawn and activate these joints that are placed and tracked on your body through your camera. These joints are located in the hierarchy which are all named similarly to "leftWrist" or "rightHip". In this code, we look for these joints using GameObject.Find() and storing them as a transform on our script. These transforms will be useful as it stores the position of these joints on the screen. These joints are placed as two-dimensional so we can't track forward and back motions. In the boulder blade mini game, the exercise is identified as arm swings where you rotate your arms that acts as a sword swing in game. We track that motion in post estimate by checking if our wrist is above our ear or below the ear to identify as an arm swing as this is what we would expect arm swings in real life to look like.

4. EXPERIMENT

A possible blind spot within my software is the potential flaws with the post estimate used. It may not be capable of registering the movements of players and converting them into actions within the games which can lead to heightened levels of frustration along with lower levels of motivation.

The experiment that we have planned in mind will be to test out the functionality of the pose estimate within our game through multiple rounds of testing while measuring the amount of inaccuracies. The reason that we have chosen to set up our experiment this way is because after we have managed to complete the tests, we will look at the results to determine which factor is the most prominent among the rest, and focus our attention on resolving that issue first, before turning to the rest of them, in order to minimize the amount of problems that can cause inconveniences.

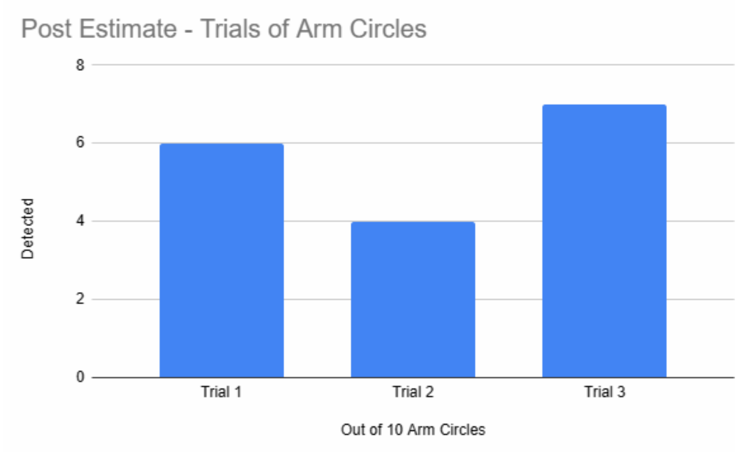

Figure 8. Figure of experiment 1

After three trials of testing ten arm circles in a row for accuracy, the graph resulted in values of six for the first trial, four for the second trial, and seven for the third trial. The mean was 5.67 arm swings detected out of 10, while the median was six. The lowest value out of these three trials was a value of four detected arm circles. On the other hand, the highest value was seven arm circles. A surprising result was that the second trial had an unsatisfactory lack of detected arm circles, which was lower than expected. This could be a result of performing the actions too swiftly and/or being too close to the sensors preventing proper detection of the movements. From this, it can be assumed that the thing that has the biggest effect on our results are the distance from the sensors and the speed of the motions.

5. RELATED WORK

In October, 2021, scientists from Brazil and the United Kingdom utilized the game "Kinect Adventures" for a trial involving type 1 diabetics [9]. Their solution is similar to ours in that both utilize cameras to track motion, getting players to move about and have fun while burning more calories. However, something that weighs down the efficiency of Kinect Adventures is that it may be heavy in terms of cost, requiring expensive items such as a television or a computer [10]. Our solution is much cheaper, doesn't require nearly as much equipment to play, and is aimed towards a larger group, being younger audiences such as children.

Between 2016 and 2018, a study involved reviewing databases while comparing players of Pokemon Go to ordinary people, and at the end, the game was linked to walking longer and further[11]. Pokemon Go uses a GPS system to place key structures, encouraging players to explore their surroundings to reach "Pokestops" and gyms for purposes such as gathering resources and catching Pokemon. Another study in 2016 showed that over 30 days, people who were engaged with the game increased activity by rates higher than 25%[12]. While their solution is ideal for encouraging players to take extended walks over longer distances, our solution is capable of enticing users to participate in higher intensity exercise activities over a much shorter duration of time, with health benefits becoming apparent much sooner.

According to a study done on Dance Dance Revolution (DDR) in 2013, the game is able to provide adequate exercise to adults that were familiar with exercise, with levels as high as 8.0 in the METs system [13], which compares the metabolic rate while engaging in intense activities to the metabolic rate while at rest, since it is considered a rate at which energy is expended during a period of time [14]. Another study in 2009 revolving around Dance Dance Revolution explored using the game to improve conditions that caused health risks in kids that were above average in weight [15]. While the two studies that were involved with Dance Dance Revolution were able to show positive results in exercise and resolving health conditions, they do not cover the issue of motivation in people nowadays. DDR also is a dance game that involves much more vibrant colors, which may disorient younger audiences that are not used to complex scenery. On the other hand, our solution is much more simplified and catered towards children and teens who may struggle with motivation by making it easier to navigate and play, while also using game styles that would be familiar to kids.

6. CONCLUSIONS

A notable limitation we encountered in our project revolved around the artificial intelligence (AI) utilized for pose estimation. The AI was not fully trained to accurately recognize every exercise, leading to occasional disruptions in gameplay as it failed to interpret player movements correctly. Given more time to refine the game, we would dedicate additional efforts to extensively test and fine-tune the AI. This could involve identifying factors causing inaccuracies, such as removing obstacles and optimizing lighting conditions in the room. An alternative approach would be to explore a pose estimation version better suited to our project's specific needs, encompassing the six different exercises. A more compatible version could efficiently detect player motions and seamlessly translate them into character actions, minimizing disruptions and ensuring a smoother gaming experience. In conclusion, despite the encountered limitation, we take pride in what we've achieved within the given time frame. Our hope is that the success of our project serves as inspiration for children struggling with motivation, encouraging them to find joy in exercising while reaping the associated health benefits. Our commitment remains steadfast in promoting both physical activity and enjoyment for users of all ages.

REFERENCES

[1] Whitehead, Anthony, et al. "Exergame effectiveness: what the numbers can tell us." Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games. 2010.

[2] Nelson, Karin M., Gayle Reiber, and Edward J. Boyko. "Diet and exercise among adults with type 2 diabetes: findings from the third national health and nutrition examination survey (NHANES III)." Diabetes care 25.10 (2002): 1722-1728.

[3] Townsend, Marilyn S. "Obesity in low-income communities: prevalence, effects, a place to begin." (2021).

[4] Ten Velde, Gabrielle, et al. "Physical activity behaviour and screen time in Dutch children during the COVID‐19 pandemic: Pre‐, during‐ and post‐school closures." Pediatric Obesity 16.9 (2021): e12779.

[5] Ahluwalia, Namanjeet, Steven M. Frenk, and Stuart F. Quan. "Screen time behaviours and caffeine intake in US children: findings from the cross-sectional National Health and Nutrition Examination Survey (NHANES)." BMJ Paediatrics Open 2.1 (2018).

[6] Warburton, Darren ER, et al. "A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults." International journal of behavioral nutrition and physical activity 7.1 (2010): 1-220.

[7] Griffiths, Mark. "Can videogames be good for your health?." Journal of health psychology 9.3 (2004): 339-344.

[8] Ness, Kirsten K., et al. "Predictors of inactive lifestyle among adult survivors of childhood cancer: a report from the Childhood Cancer Survivor Study." Cancer 115.9 (2009): 1984-1994.

[9] Mueller, Florian'Floyd, et al. "Jogging over a distance: the influence of design in parallel exertion games." Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games. 2010.

[10] Boulos, Maged N. Kamel, and Stephen P. Yang. "Exergames for health and fitness: the roles of GPS and geosocial apps." International journal of health geographics 12.1 (2013): 1-7.

[11] Li, Yaoyue, et al. "Pokémon GO! GO! GO! The impact of Pokémon GO on physical activity and related health outcomes." Mhealth 7 (2021).

[12] Althoff, Tim, Ryen W. White, and Eric Horvitz. "Influence of Pokémon Go on physical activity: study and implications." Journal of medical Internet research 18.12 (2016): e315.
[13] Naik, Rutika Akhil. Physiological and psychophysiological changes with XBOX Kinect Dance Central training. Diss. Long Island University, The Brooklyn Center, 2013.
[14] Roland, J. "What exactly are METs, and what should you know about them." (2019): 1-12.
[15] Murphy, Emily CS, et al. "Effects of an exercise intervention using Dance Dance Revolution on endothelial function and other risk factors in overweight children." International Journal of Pediatric Obesity 4.4 (2009): 205-214.