Playing Darts in Augmented Reality

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ABSTRACT

This paper is about an augmented reality (AR) game offering users a virtual dart-throwing experience. Using the accelerometer and gyroscope sensors embedded in a smartwatch, players can enjoy realistic gameplay by physically mimicking the motion of throwing darts.

1 INTRODUCTION

The game showcases the potential of smartwatch technology in delivering immersive AR experiences, pushing the boundaries of gaming on wearable devices. The paper further describes the gameplay and implementation of the game.

2 DARTS

Before discussing the game, it is important to understand what darts is and what the rules of the game are.

2.1 Setup

To play darts, a specific setup is required. This is precisely standardized. The playing field of a dart board is 34 cm wide. The exact center of the dartboard has to be 173 cm above the ground. The players take turns and each player has to throw 3 darts at the target in a row. They must stand 237 cm away from the dartboard. This line is also called oche and must not be crossed with the foot. The dartboard's playing field consists of 20 numbered segments ranging from 1 to 20. Each segment has an outer ring that scores twice as many points and an inner ring that triples the points. In the middle is the Bullseye, which is divided into the Single Bull (50 points) and the Double Bull (25 points).

2.2 Gamerules

Darts can be played in many different ways. The most common variant is 501. Each player starts with 501 points and has to play down to exactly 0 points. Usually, the last throw must be completed with a double field, but it can also be played with single fields. If one ends up below 0 points, the move is called a bust, and the player gets reset to the score before the turn. If one plays the double out variant (completing with a double field), a player cannot have just one point remaining because there is no longer a corresponding double field to complete the game which is why the player will be reset too to the score before the turn. The first player to reach exactly 0 points wins the game.

3 DESIGN

The game should be as realistic as possible to real dart throwing without having to set up the necessary setup. The dartboard is replaced by a printed image. The arrows are only thrown virtually by mimicking the throwing motion. A smartwatch on the wrist measures this movement. Using the corresponding smartphone app, the dartboard is projected over the image. Using Augmented Reality, the throw line (see Fig. 1) is placed on the ground at the correct distance.

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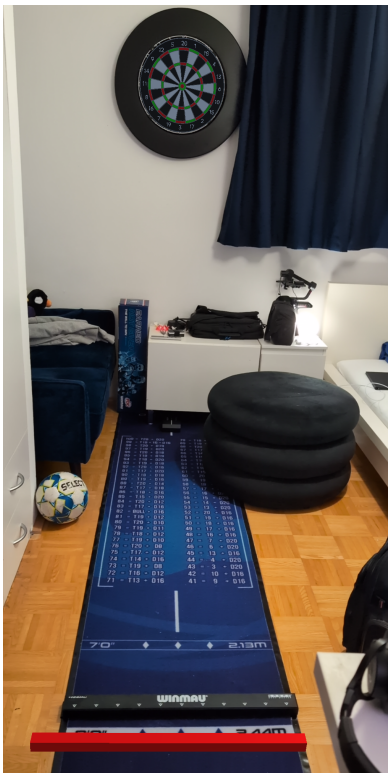

Figure 1: The projection of the dartboard including the virtual oche compared to a real setup. The dartboard might look real, because the dartboard being used as the AR target.

3.1 Gameplay

After opening the game, the user has to film the given image or a real dartboard with the camera. A virtual dartboard is displayed over the image. Before darts can be thrown, a smartwatch must be connected to the smartphone app. The IP address of the smartphone can be entered in the smartwatch app. The Communication works via a UDP socket on port 4455. This port may need to be enabled in the firewall. To start the game, the smartwatch needs to be calibrated. An animation is played on the dartboard showing how the smartwatch has to be held in front of the bullseye for calibration. The calibration is only suitable for the right throwing hand. Wearing the watch on the left arm is not possible. If the smartwatch animation disappears, the calibration is successful. The first dart appears in front of the camera. In general, a dart can be repositioned using the smartwatch. An image can be seen in the app, which is recognized by the camera of the smartphone. As long as the image is visible, the dart moves with the image (see Fig. 2). If the arm or the smartwatch is turned backward so that the image is no longer visible, the dart remains in the air and one can start aiming. Ideally, the camera is moved in a way that the arrow floats between the camera and the dartboard to be able to aim better. The rotation of the dart corresponds to the rotation of the arm or respectively that of the smartwatch. This allows you to determine in which direction the arrow should fly. The arrow

Figure 2: The dart can be positioned by rotating the smartwatch towards the camera. The image on the app gets recognized and is used as a marker.

Figure 3: The dart adapts to the orientation of the smartwatch.

is released when the arm moves fast enough. A natural throwing movement is sufficient. The challenge is that the arrow continues to point into the targeted segment during the throwing movement. The points thrown are shown on the dartboard and the current score is below it. There is an invisible wall behind the dartboard. However, it may be possible to throw the dart over the wall or into the ground. This means that the game does not recognize that the arrow has missed. In this case, the image on the smartwatch must be used to cancel the throw and position the next dart.

4 Implementation

The implementation took place in several parts. First, a Wear OS app was developed to detect the throwing motion, the processed data was applied to a dart in Unity and lastly, game logic was developed.

4.1 Sensor Data Processing

When throwing darts, two aspects are crucial: Direction of Throw and Throw strength.

Direction of Throw The direction of the throw can be measured using the phone's gyroscope. The Android API provides a function to calculate the orientation of the smartphone from the rotation matrix of the gyroscope. More precisely, azimuth, pitch and roll are calculated. Based on the Unity coordinate system, azimuth is the rotation around the y-axis, pitch is around the x-axis and roll is around the z-axis. The smartwatch orientation is sent to the smartphone and applied to the dart. The dart rotates with the arm (see Fig. 3). Since the dartboard is not always hanging in the same direction and the smartwatch's gyroscope can drift, calibration is necessary at the beginning of the game so that the arrow points in the direction of the dartboard.

Throw Strength The throwing strength is calculated using the smartwatch's acceleration sensor. It provides the acceleration in all axes relative to the smartwatch. If the relative acceleration were applied to the dart, this would not correspond to reality, since darts move relative to the earth. Therefore the acceleration must be calculated relative to the earth. First, the acceleration due to gravity itself must be removed. This is done by a simple subtraction on all axes.

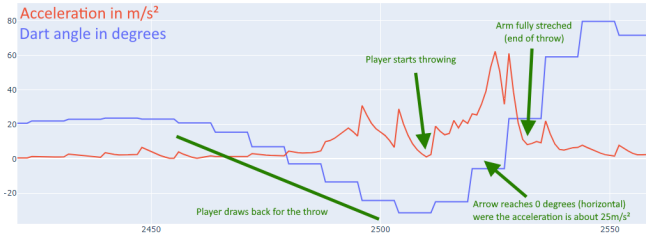

Figure 4: Diagram showing the orientation and total acceleration of the wrist during a throw.

Beforehand, a low-pass filter is applied to avoid short-term fluctuations in gravity. The conversion to acceleration relative to earth is done by using the rotation matrix created from the gyroscope's raw data. The inverted rotation matrix is multiplied by the device-related acceleration to obtain the earth-related acceleration.

4.2 Throwing

It is now important to estimate the time of release so that the acceleration at this time can be used for the virtual dart throw. A natural throwing movement builds up the acceleration. In Fig. 4 you can see the total acceleration in orange and the angle of the dart or wrist in degrees. It is clearly visible that the angle initially becomes smaller and smaller, or respectively that the arm is more and more angled towards the body because the player draws back for the throw. At the time the angle of the arm reverses again, the acceleration is almost zero. This is ultimately the starting point of the throw. When the wrist is at an angle of 0 degrees, that is the arrow is almost exactly parallel to the ground, the acceleration is approximately 25 m/s^2. Through further observations, 25 m/s^2 turned out to be a good threshold to count as the release time. Accordingly, the dart is released exactly when this threshold is reached. The command to throw the dart is sent to the smartphone. Only the total acceleration is sent to the phone, as the darts orientation is constantly updated anyway. This threshold allows for real-time throwing. An improvement for this is discussed in 5.

4.3 Physics and Collision Detection

When a dart is thrown, gravity is activated for the rigid body and the forward speed is determined by the acceleration of the smartwatch. If the dart isn't stuck anywhere yet, a linecast check is performed on every frame to see if the dart hits an obstacle. When an obstacle is hit, the game checks whether it hit the wire of the dart board, a dart segment or something else such as the edge of the board or the wall. In the dartboard model, each dart segment is a single object. The same script is assigned to each of these segments. For each segment, the global variables for the points and the type of segment (single, double, triple) are adjusted accordingly. This allows the game to determine the points. If the dart hits the wire, the dart is moved in a random direction so that it does not get stuck on the wire. If the wire is not hit, the dart's position will be frozen. Depending on whether the hit area is a segment or not, either a hit or a miss is registered.

4.4 Game Logic

In terms of game logic, there's not much going on. After the player starts the game, the first turn begins. A turn always consists of 3 throws. With each throw, a new dart is instantiated and placed in front of the camera. It can be positioned somewhere else with the image on the smartwatch. After each throw, either a hit or a miss is registered. If it's a hit, the score is updated. If it's a miss, nothing else happens except that the next throw starts. If the score becomes negative, it is a so-called bust. This resets the player to the score before the move, as one has to reach exactly 0 points. If the score reaches 0 after a hit, the game ends. Due to the difficulty, it is not necessary to hit a double field to end the game with 0 points. Any field can be hit for this.

5 Possible Improvements and Conlusion

If a small delay in the release is accepted, the release time could be better estimated, as this would allow smoothing and resampling of the gyroscope values. Resampling is necessary because, in Android, the calibrated gyroscope delivers values less frequently than the acceleration sensor.

This game proves that virtual dart throwing would work surprisingly well thanks to the precise sensors of a smartwatch if the time of release was better estimated than before. However, the most accurate way would be to use a button between your fingers. It would be even better if a controller was attached to the hand that could be permanently tracked to position the dart. The only button on the controller for release detection could then be operated with your thumb.