AN INTELLIGENT AND DATA-BASED SKATE ANALYZER TO ASSIST IN ANALYZING MOVEMENTS OF SKATE ON ICE

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ABSTRACT

Ever since the start of Figure Skating, there has been an emphasis on skating technique, especially in the step sequences of a skater's choreography [1]. But Figure Skaters often are not able to detect the motion, edge, or placement of their blade on the ice without watching themselves skate. The solution to this problem would be to have a skate analyzer. A skate analyzer would record the movements of a skate on ice and one would be able to playback the recorded data and view their skate motion precisely [2]. Three main components that my project links together are the QTPY-ESP 32 microcontroller, the sensor that combines the accelerometer, gyroscope, and magnetometer, and the SD card reader. The QTPY-ESP32 is a microcontroller that acts as a main computer controlling the whole board. The QTPY is then connected to a sensor board through an I2c protocol. Then, through an SPI protocol, the QTPY is connected to an SD card reader. After the skater is finished recording, they can insert the SD card in a computer, upload the data into the app, and play it back. There is also a slider on the top of the screen that the skater can slide back and forth to view the skate at specific times in the file. This would be a great technology to use for skaters as they can playback their movements on ice and improve their technique [3].

KEYWORDS

Figure skate, Ice, Analyzer

1. INTRODUCTION

Ever since the start of Figure Skating, there has been an emphasis on skating technique, especially in the step sequences of a skater's choreography. Because of this emphasis, skaters are more attentive to the movements of their skate on ice. But Figure Skaters often are not able to detect the motion, edge, or placement of their blade on the ice without watching themselves skate. Especially when they are practicing by themselves. They would need to record themselves or have someone supervise them while they are practicing in order to productively get better in their technique.

The solution to this problem would be to have a skate analyzer. A skate analyzer would record the movements of a skate on ice and one would be able to playback the recorded data and view their skate motion precisely. There would be hardware with multiple sensors to record data based on the movements of the skate and then the data would be processed. After that, a skater can upload this data onto an app that would have a 3D model of a skate on ice, which would move

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based on the data [4]. Then, the skater would be able to see whether the skate moved the wrong way, fell on the wrong edge, or did other wrong techniques.

The first blindspot that I wanted to test out was how to position the board on the shoe, whether it affected the accuracy of the data, and if the material used to secure the board on the shoe mattered. The second blind spot that I wanted to test out was how the gravity would affect the board in different directions. For both of theseblindspots, we set up experiments with different combinations of placements of the board, materials used to secure the board, and the different directions of gravity. Then, we would record data using each situation. Then, using the wide range of data collected, we would upload them and see which provided the best results.

The three methodology comparisons were all trying to test out their wearable device. The first experiment developed a prototype jump monitor for figure skaters [5]. They wanted to measure jump count, jump height, and rotation speed by using an IMU attached to the lower back [6]. These jump monitors could help skaters and coaches balance injury and performance concerns. The second experiment sought to improve on a previously developed wearable device named the IceSence device attached to the lower back. This study wanted to determine the force data for off-ice jump landings. This study demonstrates that their technology may be able to offer information that is helpful in upcoming figure skating studies. The third study put forth a new method for automatic identification of ice hockey skating stires as well as a technique to detect ice contact and swing phases of individual stries. After analyzing the data using a 3D accelerometer attached to the hockey skate, they proved that this technology is precise, user friendly, and efficient.

2. CHALLENGES

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

2.1. How to Place and Connect all the Components on a Board

One problem that we can experience is how to place and connect all the components on a board small enough to fit on the skater's shoe [14]. The components might not fit, or the soldering might cause problems, and not connect correctly. To solve this problem, we could make sure that all the components are bought small enough by measuring how big of a board can fit on the skater’s shoe. We could also possibly consider what material we would like the board to be, as the flexibility of the board would also contribute to solving the problem. For a secure connection, we could plan out how we will solder, and if soldering does not work in particular times, we could use cables to connect them.

2.2. Making Sure the Data is Correctly Processed and Presented

Another problem that we could experience is making sure the data is correctly processed, presented, and that the skate will be moving accordingly. We can program the data to be stored in charts and categorize them in a way that is easy for us to use. Additionally, we can code specific functions to calculate the velocity, position, and acceleration of the skate based on the data, and present it on the screen accurately. Then, we can also add specific variables in Unity, such as the position, velocity, and acceleration, so that the user can track these data instantaneously while watching the playback of their skate movements [15].

2.3. Deciding how the Board Should be Placed

Lastly, a problem that we can experience is deciding how the board should be placed on the skater's shoe so that it fits and is influenced by gravity properly. A way we can solve this is first find a way to lock the hardware board on the shoe. Either we can tuck it in the sides of the shoe, or use a velcro and tie it to the laces of the shoe. After that, we can experiment with the direction of the placement on the shoe, either horizontally or vertically, and see the resulting data. With the different outcomes, we can code to see how gravity effectively acts on the shoe so the data can come out correctly.

3. SOLUTION

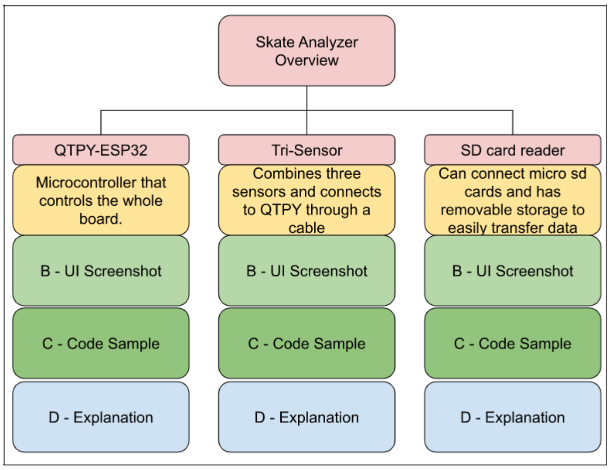

Figure 1. Overview of the solution

Three main components that my project links together are the QTPY-ESP 32 microcontroller, the sensor that combines the accelerometer, gyroscope, and magnetometer, and the SD card reader [7]. The QTPY-ESP32 is a microcontroller that acts as a main computer controlling the whole board. The QTPY is then connected to a sensor board through an I2c protocol. Then, through an SPI protocol, the QTPY is connected to an SD card reader [8]. When the skater is about to record data, he or she can position the board on their skate and turn the microcontroller on and the whole board will start to record data. The whole board will be powered through a battery that is connected with a battery controller. Then, as the skater moves, the sensors will detect the movements and all that motion data will be stored in the SD card inserted into the reader. After the skater is finished recording, they can insert the SD card in a computer, upload the data into the app, and play it back. There is also a slider on the top of the screen that the skater can slide back and forth to view the skate at specific times in the file. At the bottom of the screen, there will be the position, velocity, and acceleration data of the skate while it is moving. Then, the skater can also control the view, by pressing W, A, S, D, to represent up, left, down and right, respectively. This allows the skater to follow the skate as it moves in different directions.

One of the components that we used is the QTPY-ESP 32 microcontroller. This acts as a computer that controls the whole board. Turning this on allows the whole board to work. This component could work with WiFi, but in our project we chose not to incorporate this feature. It has a USB type c charger that can be used to charge the battery.

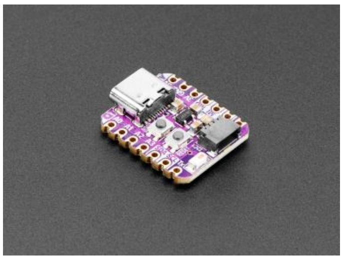

Figure 2. The microcontroller

```
def getSensorDataAsCSV(startime):
    deltaTime = (time.monotonic_ns() - startime) / 1000000000
    acc = acc_gyro_sensor.acceleration
    gyro = acc_gyro_sensor.gyro
    mag = magnetometer.magnetic

    line = str(deltaTime) + ','
    line +=  str(acc[0]) + ',' +  str(acc[1]) + ',' +  str(acc[2]) + ','
    line +=  str(gyro[0]) + ',' +  str(gyro[1]) + ',' +  str(gyro[2]) + ','
    line +=  str(mag[0]) + ',' +  str(mag[1]) + ',' +  str(mag[2])

    return line, [deltaTime, acc[0],  acc[1],  acc[2], gyro[0],  gyro[1],  gyro[2], mag[0],  mag[1],  mag[2]]

def getSensorDataAsJSON():
    return {
        'acc': acc_gyro_sensor.acceleration,
        'gyro': acc_gyro_sensor.gyro,
        'mag': magnetometer.magnetic
    }
```

Figure 3. Screenshot of code 1

```
def printAccel(data):
    print(data[1],data[2],data[3], sep='\t')


with open(filepath, "w+") as f:
    print('creating', filepath)
    f.write('second,acc_x,acc_y,acc_z,gyro_x,gyro_y,gy
    f.flush()
    startTime = time.monotonic_ns()
    acc_gyro_sensor.accelerometer_range = 1
    while True:
        #data = str(getSensorWithTime(startTime))
        csv, data = getSensorDataAsCSV(startTime)
        printAccel(data)
        print(acc_gyro_sensor.accelerometer_range)
        f.write(csv +'\n')
        f.flush()
        time.sleep(0.1)
```

Figure 4. Screenshot of code 2

The first code sample gets the timestamp from the microcontroller. Then, we save the accelerometer data into the variable acc, gyroscope data into the variable gyro, and magnetometer into the variable mag [9]. After this, we get the data from the SD card. We turn them into a single string to use later. Then, for the second sample, we create a file to store the data into. We add titles for the column, such as seconds, acceleration, gyroscope, and magnetometer for x, y and z axis. Then we have a while loop and for every 0.1 second we add a new column with new data.

Another component that I used is the sensor. The sensor conveniently combines the accelerometer, gyroscope, and magnetometer into one board. The accelerometer measures the acceleration forces (including gravity), the gyroscope senses the direction and speed (in degrees per second) of rotation, and the magnetometer points to the strongest magnet force (usually the magnetic North Pole), respectively. It is connected with the QTPY through an I2c protocol.

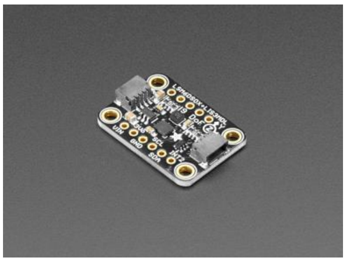

Figure 5. The sensor

The third component is an SD card reader [10]. This SD card allows us to insert or connect micro sd cards so we can save the data on the device based on the movements of the skate. This SD card reader also has removable storage so we can easily transfer the data to a computer.

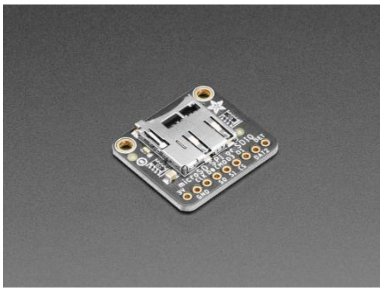

Figure 6. The SD card reader

4. EXPERIMENT

4.1. Experiment 1

One possible blind spot that I want to test out is the accuracy in the detection of the motion by the sensors. For example, sometimes the sensors would not the placed correctly, and therefore would not be giving us clear data.

We could set up an experiment where we would try different placements of the board and see the outcomes of the data. For example, the board can be put horizontally, vertically, or diagonally, based on the shoe. There could also be angles, such as slanted and put on the tongue of the shoe, or upright tucked into the edge. Different angles and positions might result in different data outcomes. Additionally, there can be different ways to secure the board onto the shoe. This can also affect the data. Therefore, we need to experiment with these two factors and find the best combination for accuracy of the data.

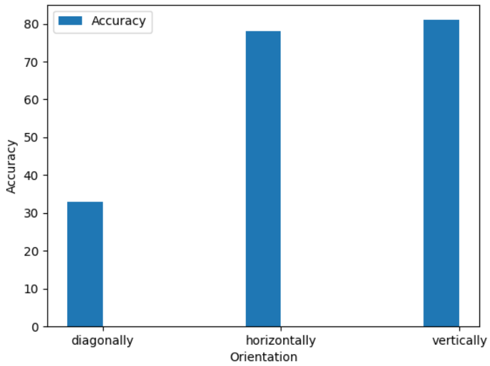

Figure 7. Graph of experiment 1

Here we can see that the orientation of the board doesn't have much difference when placed horizontally or vertically but there is a big drop in accuracy when placed diagonally. I believe this is because placing the board diagonally consistently at the exact same angle is very difficult. Place the board on board diagonally. Additionally, the orientation of the board may also affect the stability of the board, which can impact accuracy. When the board is placed horizontally or vertically, it is more likely to remain stable and not wobble or shift during use. However, when the board is placed diagonally, it may be more prone to wobbling or shifting. This is due to the limited ways I can attach the board to the skate.

4.2. Experiment 2

Another potential blindspot is the way gravity acts on the board and affects the data. Although there are ways listed before that could be used to solve this problem, sometimes just a bit of angle difference can result in the gravity not acting on the board correctly.
First, we need to solve the first blind spot of how to place the board and what to use to secure it. After deciding that, we need to experiment with gravity. There could be different directions in which the gravity acts on the board. However, we can also play with different combinations of placements of the board and directions of gravity acting on the board. With different placements come different programming of the direction of the gravity. Based on the outcome of that experiment, we can find the best combination that would give the most precise data so the skate can move accurately.

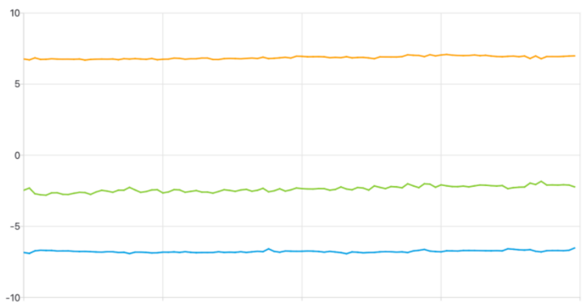

Figure 8. Diagonal Diagram

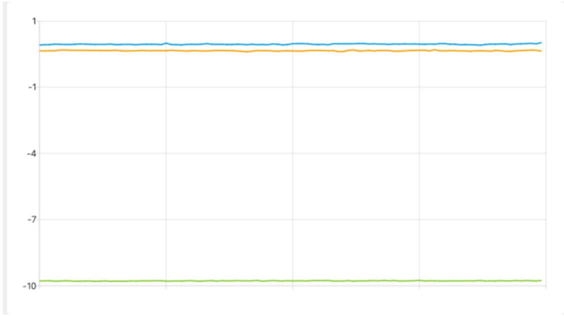

Figure 9. Vertical Diagram

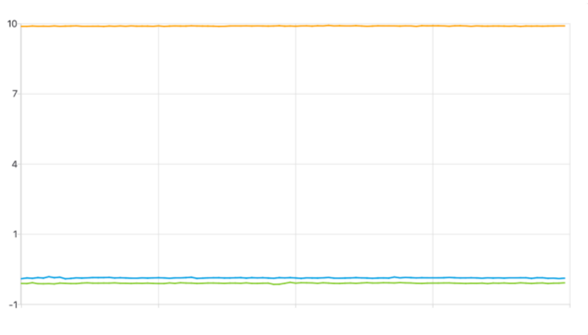

Figure 10. Horizontal Diagram

Orange: Z-Axis
Blue: X-Axis
Green: Y-Axis

The data shows that mounting the board diagonally causes the most noise. This is because of how unstable the board is mounted on the skate. Having the three axes be non-zero on the diagonal test makes canceling out the effects of gravity difficult. This also makes determining the orientation of the skate harder as well. The axis closest to zero between the horizontal and vertical orientation is the X-axis in the vertical. The Y-Axis on the vertical orientation is also fairly consistent at -9.8. This makes canceling the effects of gravity much easier as we only have to worry about gravity on one axis. This will also make finding the orientation of the board easier as well. Since the vertical mounting of the board give the most stable and simplest data to manipulate while easy to mount, so we designed our mount and code to correspond the a vertically mounted board.

5. Related Work

Dustin A Bruening’s study developed a prototype jump monitor for figure skating [11]. He wanted to determine whether he could use an inertial measurement unit, or IMU, to measure jump count, jump height, and rotation speed. Skater’s wore an IMU attached to the lower back and were filmed with a camera for validation in the jump height. Overall, his study's findings suggest that a single waist-mounted IMU can accurately identify multi-revolution jumps and measure rotation speeds. The algorithm's leap height estimation accuracy should be improved. These features in a fully integrated jump monitor could help skaters and coaches balance injury and performance concerns.

By carefully measuring the power of on-ice landings, Sarah Ridge's research aims to further knowledge of injuries in figure skating and have an impact on training methods, injury preventive measures, and rehabilitation procedures [12]. The study makes use of a wearable IceSense device attached to a skater's shoe. This study proposes that the most accurate force data for off-ice jump landings can be obtained by calibrating the strain sensors against a load cell situated above the skate blade using a controlled drop method. Data from a single jump landing on the ice demonstrate that this technology may be able to offer information that is helpful in upcoming figure skating studies.

Stetter's research demonstrates a new method for automatic identification of ice hockey skating strides as well as a technique to detect ice contact and swing phases of individual strides by quantifying vibrations in 3D acceleration data during the blade-ice interaction [13]. The data was then analyzed using a 3D accelerometer attached to a hockey skate. To test the new method's precision on a variety of forward stride patterns for temporal skating competitions, the predicted contact times and stride times for a series of five consecutive strides were validated. These findings demonstrate the validity of the novel method for determining strides, ice contact, and swing phases during ice hockey skating. This technology, which allows for in-field ice hockey testing, is precise, user-friendly, and efficient.

6. CONCLUSIONS

Some limitations to my project might be the fact that the ice size displayed on the screen where the skate can move is a bit small. Sometimes if the skater is skating in a larger ice rink while having the device on and tracking their movements, after they upload their data onto the app, the skate might fall out of the ice displayed on the screen. So if I had time, in the future I would make this change. Additionally, I would like to possibly add another skate so then both shoes can be tracked at the same time. For example, sometimes one foot would constantly be off the ice while practicing, and if the device is attached to the shoe in the air, then the results would not be helpful. But if both of the shoes appear on the screen, then the skater can visualize their movements of both their shoes better.

This project aims to assist skaters to better visualize their movements on ice by recording the motion of their shoe on ice using a device board that incorporates a microcontroller, sensors, sdcard reader, and a battery controller. They can upload their data onto the app and closely view their movements and make changes to their techniques on ice.

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