Self-Contained Analytical Skating Form Tracker

Project Proposal

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1 Introduction

1.1 Objectives

As an essential part of figure skating and hockey, ice skating is not only the foundation of the professional plays, but also a widely popular recreational sport for the public all over the world. The increased speed and reduced friction on ice often brings about rising level of safety issues. Therefore, ice skating calls for extreme precision and intricate body position. However, most skaters have not received formal training on their skating forms. Even for people with professional instructors, the traditional ways of coaching they get relies heavily on visual inspection and depends on the instructor's experience. Thus, many skaters, including some professionals, are unaware of their bad habits in skating form, which might lead to more risks of injury.

Our goal is to design an affordable, easy-to-wear device that can help users increase efficiency in skating while reducing the chances of injury. This device can track the skating forms and provide feedback to the user. It will assist the process of evaluating the skater performance and identify some subtle, unwanted habits that are hard to notice through visual inspection. We aim to make this design small and straightforward to use, while being affordable so the general public can utilize its benefits and improve upon their skating forms.

1.2 Background

In the past decade, researchers have worked on the analysis of on-ice biomechanics measurements. A team from University of Calgary, Canada implemented a system to investigate the forward skating technique [1]. Their measurement system includes EMG electrodes, electrogoniometers, accelerometers, instrumented insoles, and data acquisition unit. Another project carried out at McGill University, Canada focused on analyzing dynamic forces during skater landing using specially modified skates and a force transducer system[3]. The main issue with the previous projects on skating data collection is the high cost to replicate these devices. They require either a multitude of expensive sensors or customized skates with special design. In addition, the convoluted connection between devices make the system cumbersome and inconvenient for frequent use. All these factors make the existing systems prohibitive to the public.

Based on the above analysis, we aim to make our skate form tracker easy to use and highly affordable. It can be easily attached to the front of the skates near the laces. Since it's lightweight and small, it will be as non-invasive as possible to the user. It will also eliminate the complex wire connection so it's straightforward to use for the public. Ideally, the price of the device should be below $20.

1.3 High-Level Requirements

- The device must be durable, water resistant, and lightweight.
- The device must be able to capture all necessary data needed in order to analyze the user's skating form.
- The device must give useful feedback to the user based on the collected data.

2 Design

2.1 High Level Description

Our project features 2 almost-identical units, one for each foot. One is designated as the master unit, and the other the slave. Upon startup, the units should be in a rest state until the master unit initiates the pair up/syncing procedure (which in turn is initiated by the user pressing the button). The success of this sequence will be indicated by the status LED. Once paired and synced, the device will begin data collection, during which the microcontroller will sample the IMU and the force sensor in specified time intervals, and store them on-board. After a period of inactivity (or when directed), the data collection ends, and the slave unit will transmit all its collected data to the master unit. The master unit will combine the data collected from both devices and store them into the microSD card for post processing on the computer.

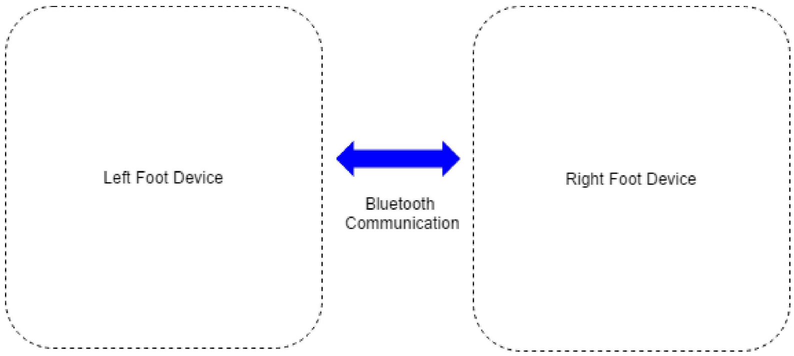

Figure 1: High-level Overview

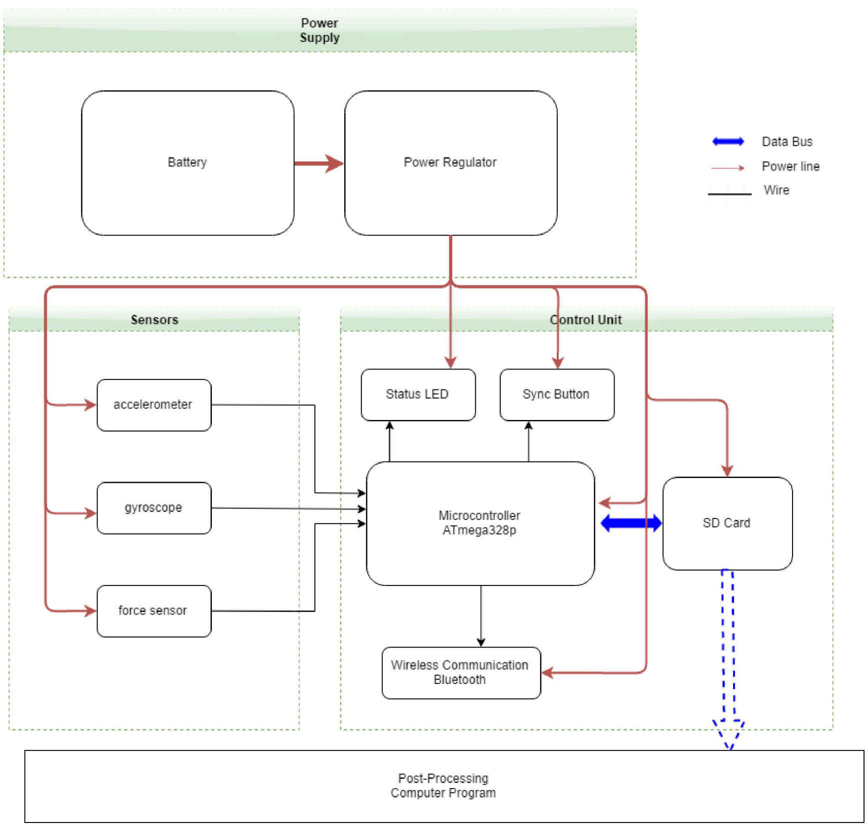

Figure 2: Block Diagram

2.2 Control Unit

The control unit manages data collected by the sensor and controls the SD card for data storage. It also provides a user interface with LEDs and buttons.

2.2.1 Microprocessor Unit (MPU)

The microprocessor, ATmega328p, is the central piece of the control unit. It manages memory allocation for logging, user inputs(buttons) and the communication with the wireless communication module and controls the status LEDs. It communicates with the sensors block mainly through SPI, and writes the data read into the SD card, also through SPI. At the end of data collection, the slave device's microprocessor will transmit all its collected data to the master device's microprocessor through the Bluetooth module.

Requirement:

Must work with the supply voltage of 3.3VDC ± 5%

Must operate at 16MHz, and sample the sensors at ~50Hz

2.2.2 microSD Card Interface

It provides memory for data storage. The lowest class of microSD cards operate at ~2MB/s, which is higher than what we require. Therefore, a speed requirement is not listed.

Requirement:

Must be able to support (read/write) a FAT32 formatted microSD

Must work with the supply voltage of 3.3VDC ± 5%

Must be able to store 10 minutes of continuous movement data

2.2.3 Sync Button

This is the user input button to sync the timing between devices on left and right foot.

Requirement:

The button must exist, and be functional, as it is our only gateway towards commanding the device to sync up

2.2.4 Status LED

The status LED will display signal indicating if the syncing process is successful or not.

Requirement:

The status LED must emit light of multiple colors. It must work with 3.3VDC.

2.2.5 Bluetooth Communication Module

This module will handle the crosstalk between devices on the user's left and right foot. At initial set up, a syncing signal will be sent via the sync button. The communication module will receive a return signal indicating whether the syncing process is successful. At the end of data collection, the slave device will transmit all its data to the master device through Bluetooth.

Requirement:

Must work with the supply voltage of 3.3VDC ± 5%

2.3 Power Supply

The power unit supplies power for sensors and the control unit. The power source comes from a battery, which is regulated to 3.3V to supply the rest of the device.

2.3.1 Battery

A slim rechargeable LiPo battery will be used to power the device. A voltage regulator will be used to drop the 3.7V battery supply voltage to 3.3V.

Requirements:
Must be able to power the device for at least an hour
Must supply 3.7V
Capacity drop must not be substantial in colder environments (such as a skating rink)

2.3.2 Voltage Regulator

Our design requires 3.3V operating voltage for the control unit and the sensors. Therefore, a voltage regulator is needed to regulate the battery voltage to the operating point.

Requirements:
Must be able to drop the 3.7V of the LiPo down to the 3.3V ± 5% supported by the rest of the components
Must be > 80% power efficient

2.4 Sensors

The sensors collect the inertia and movement data of the user and sends it to the MPU for processing and storage

2.4.1 Inertial Measurement Unit (IMU)

Our design uses the LSM6DS3, which contains a 3-axis accelerometer and a 3-axis gyroscope. With the data collected from this sensor, we can derive the general motion the user's feet at any given time.

Requirements:
Accelerometer must be able to measure ± 3g of acceleration (range ~ ± 3g)
Gyroscope must be able to measure ± 150 degrees per second (range ~ ± 150 dps)
The IMU as a whole must operate on 3.3VDC ± 5%

2.4.2 Force Sensor

We plan to use two force sensor pads per device, attached to the toe and the heel of the sole, to supplement the data collected by the IMU.

Requirements:
Must be able to measure forces up to 300 lbs.
Must be able to operate (with the addition of the op-amp) with the 3.3 VDC ± 5% supply voltage

2.5 Risk Analysis

Most of the components in our device are compact and durable. The force sensors would be the component most likely to break. However, the force sensors are not vital for the operation of our device. Capturing data on the applied force during skating is not completely necessary for determining the form of the skater. That is because the inertial measurement unit (IMU) obtains all the minimum necessary information. Thus, we conclude that our IMU inside the sensor block is the critical component. The IMU must have a certain level of accuracy to successfully analyze the user's skating form. If the data collected varies outside of the tolerable level, then the analysis of the data would give the user inaccurate feedback. The tolerance levels for the IMU include the following:

- Accelerometer's tolerance allows data to be accurate if within 5%.
- Gyroscope's tolerance allows for +/- 10 degrees in any direction

These tolerance standards must be met for the data to be deemed accurate for analytical processing.

3 Ethics

3.1 Ethics Justification

This product is purposed to help people maximize their efficiency while skating. We believe that this purpose and the device's implementation will unlikely cause any ethical issues. We plan to stick to our purpose during the whole process, and everything will be documented for complete transparency. The documentation will also act as proof showing that we did not deviate from our original goal. Since the device is meant for common use, our design process will account for the user's safety.

3.2 Safety

Based on the design components, there are a few potential safety concerns:

3.2.1 Device Overheating

As with most electronics there is always a possibility that a device could overheat based on unforeseen circumstances. In our case, the sealed packaging might lead to increased temperature. However, this will be very unlikely because the device requires fairly low power to operate. In the unlikely chance that our device overheats, the only safety concern would be sustained burns due to handling the device. The overheating device could also damage the skates but safety issue regarding that would be minimal.

3.2.2 Hardware failure

In the case of a hardware failure, everything will most likely be contained due to the sealed packaging. There will also be no shorting issues because the boot of the skate will act as an insulator between the device and the user's foot.

3.2.3 Mounting failure

There is a possibility that mount could fail and the device falls off while the user is skating. This could cause injury to the user if the user steps on the fallen device sustains a physical injury

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