Embedded-Gyrometer

Shubham Gupta[1] *
sg7761@nyu.edu

Charles Zhu[1]
cwz2014@nyu.edu

Sarthak Gupta[1]
sg8304@nyu.edu

[1] New York University

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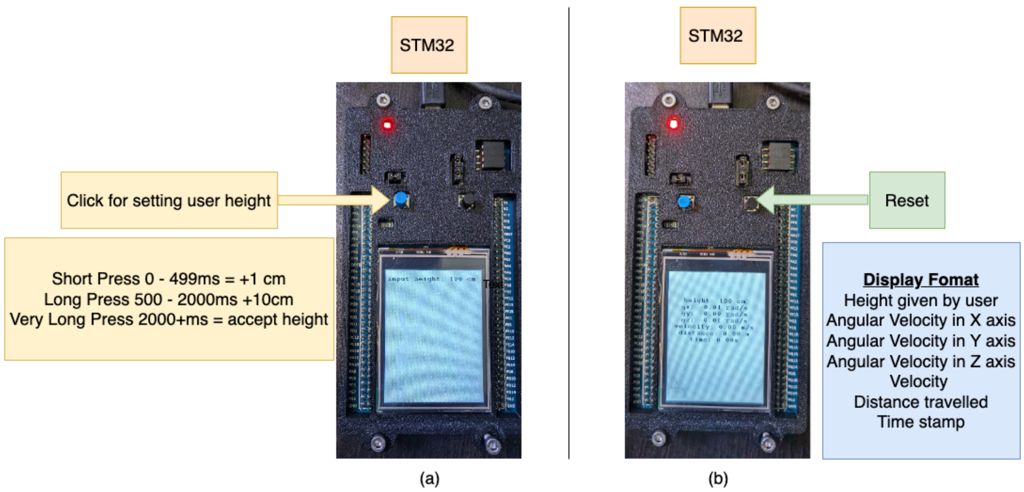

Figure 1: **Overview** our Embedded Challenge submission. **(a)** is the initial screen that shows when the STM32 F429 DISCOVERY board is first powered on. The user is required to use the blue button to input their height. **(b)** is the next screen that is shown once the height is accepted. The user can use the data shown on screen for their own purposes.

1 Introduction

The rapid advancement in embedded systems, particularly in the realm of wearable health devices, has revolutionized how we track and maintain our physical fitness. Devices such as heart rate sensors, step counters, and distance trackers have become integral in helping individuals achieve their fitness goals. In alignment with these technological strides, our semester project was centered around creating a wearable speedometer. This device, devoid of GPS technology, calculates velocity and distance traveled by interpreting angular velocities from a gyroscope.

Objective

The core objective of our project was to design and construct a wearable speedometer, capitalizing on the capabilities of the STM32F429 Discovery Board's built-in gyroscope (L3GD20). This innovative

*Corresponding author

approach required us to capture angular velocities and accurately convert them into linear forward velocity, subsequently computing the distance traveled. Such a device holds considerable promise in offering a compact and efficient solution for speed and distance measurement, particularly in fitness and health monitoring contexts. The solution we present requires no calibration step and is axis independent. We are able to estimate the velocity and distance travelled.

Hardware Requirements

The challenge necessitates the use of the following components:

- STM32F429 Discovery Board with an integrated gyroscope (L3GD20).
- Power supply or USB power bank.

Expectations

The challenge requires the following to be implemented in the solution:

- Interface the gyroscope using SPI to capture angular velocities.
- A method to store velocity data for 20 seconds, sampled at 0.5-second intervals.
- The foreward movement velocity of the user.
- The total distance traveled during the 20-second measurement period.

2 Methodology

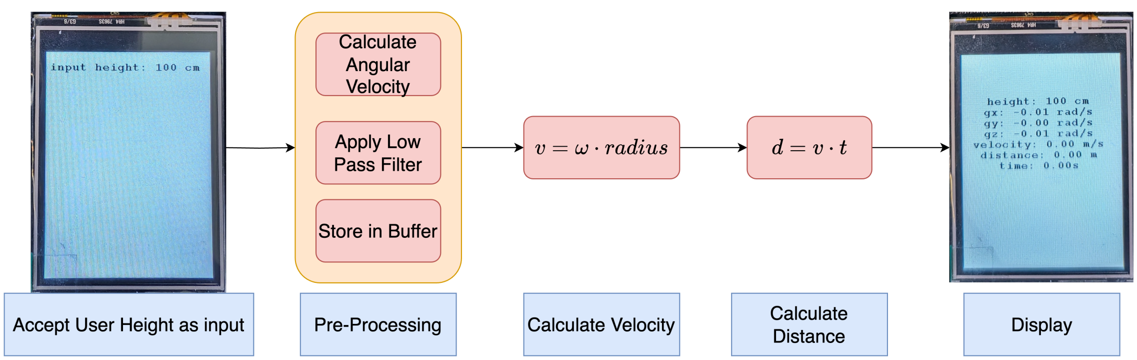

Figure 2: Overview of the system architecture of our solution.

User Input

Distance traveled by the user is dependent on their physical strides. We can approximate this by taking in the height of the user as input in centimeters. This is further shown in Table 1.

Interfacing with the gyroscope

The STM32F429 Discovery Board is interfaced with the built-in gyroscope (L3GD20) using the SPI (Serial Peripheral Interface) communication protocol. This involves setting up the SPI with the appropriate configurations ($CTRL\_REG1$, $CTRL\_REG4$, $CTRL\_REG3$) to accurately capture the gyro data.

Press	Duration (ms)	Action
Single	0 - 499	+1 cm
Single	500 - 1999	+10 cm
Single	2000+	Accept Height

Table 1: Different actions on using the blue button on the STM32 F429 Discovery.

Data Sampling and Pre-Processing

```
// Sample and Process raw data
raw_gx = (((uint16_t)read_buf[2]) << 8) | ((uint16_t)read_buf[1]);
raw_gy = (((uint16_t)read_buf[4]) << 8) | ((uint16_t)read_buf[3]);
raw_gz = (((uint16_t)read_buf[6]) << 8) | ((uint16_t)read_buf[5]);

gx = ((float)raw_gx) * SCALING_FACTOR;
gy = ((float)raw_gy) * SCALING_FACTOR;
gz = ((float)raw_gz) * SCALING_FACTOR;
```

Angular velocities are sampled every 0.5 seconds ($SAMPLE\_INTERVAL\_MS$) to get the raw data from the gyroscope in degrees per second. Subsequently, the scaling factor ($SCALING\_FACTOR$) is applied to convert it into more meaningful unit for further calculations i.e., radians per second. Following the conversion, the data is passed through a low pass filter to remove the high-frequency noise.

Linear Velocity

In determining the direction of angular velocity along the user's movement, the approach involves selecting the axis with the largest variance among the three. This ensures the effectiveness of the solution irrespective of the board's alignment. The magnitude of linear velocity is calculated by using the absolute values of angular velocity along the axis of movement and the user's leg length as the radius of rotation. An assumption has been made that the leg length is approximately 45% of a person's height.

$$v = \omega \cdot radius \tag{1}$$

Distance

The calculation of the distance traveled involves integrating the linear velocity throughout the sampling period. This is accomplished by summing the average linear velocities over the 20-second data recording period and then multiplying by the sample interval.

$$v = \frac{d}{t} \tag{2}$$

$$d = v \cdot t \tag{3}$$

3 Results and Discussion

In this project we demonstrate how to use the STM32 F429 DISCOVERY board to read user inputs using the provided interface and calculating the velocity and distance travelled by the user. We achieve this by using the L3GD20 gyroscope inbuilt on the STM32 platform. Using a low pass filter, we remove any high frequency noise. We achieve an axis independent solution by detecting the maximum variance across the X, Y and Z axis. In the end we are able to present a solution that is tailored to the user's physical height and can share detailed statistics of the sensor and their movement.

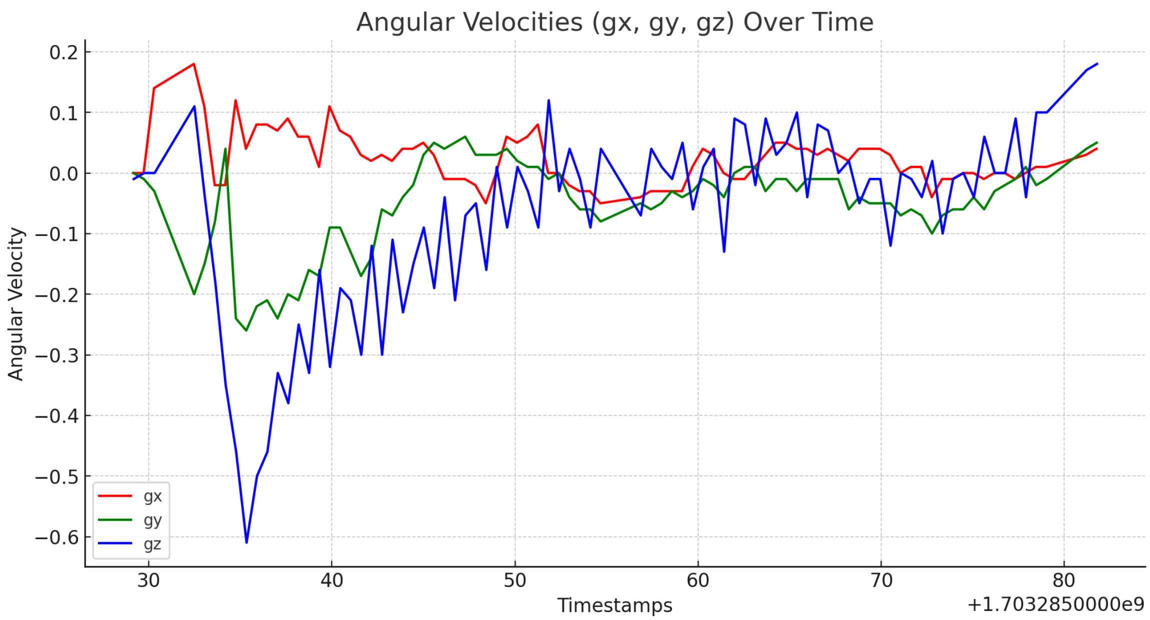

Figure 3: Angular velocity after using a low pass filter plotted using Teleplot.

4 Future Work

Future work could improve upon the sensitivity of the detection to the specific starting device orientation, or perhaps use more varied methods to convert gyroscope values to distance. The limitations of only using the gyroscope would also be mitigated with use of an accelerator.