Exercise Manual
For
SC2104/CE3002
Sensors, Interfacing and Digital Control

Practical Exercise #3:
Sensor Fusion for
Accelerometer and Gyroscope

Venue: SCSE Labs

COMPUTER ENGINEERING COURSE

SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
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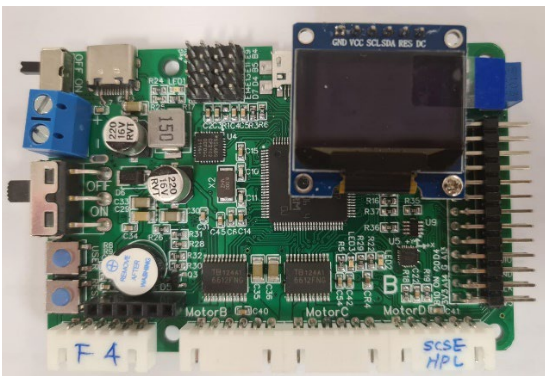
Learning Objectives

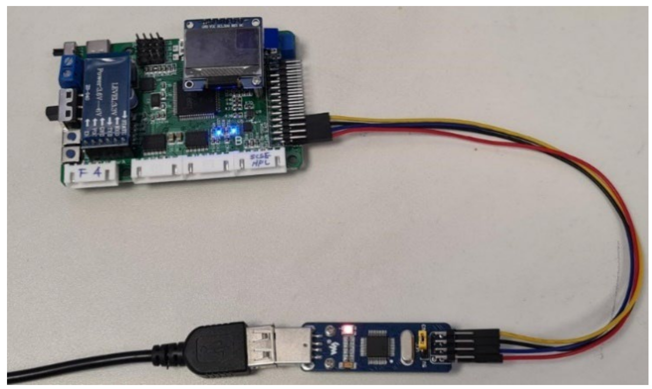
Exercise #3 is a continuation from Exercise 2. In this exercise, you will use the readings collected from the Accelerometer and Gyroscope to calculate the Roll and Pitch angles and observe their characteristics. You will then implement the Sensor Fusion technique to see how the behaviors can be improved.

Equipment and accessories required

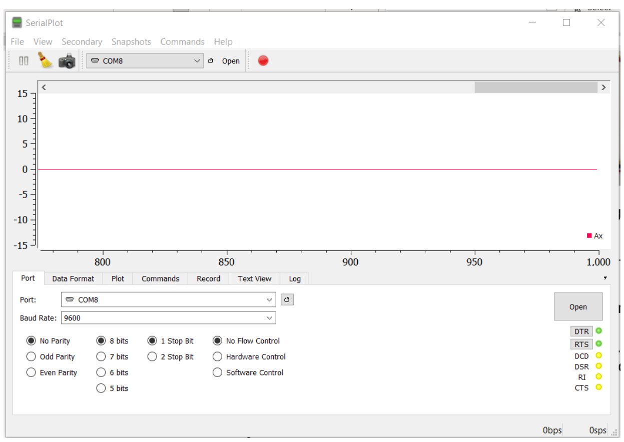
i) One desktop computer installed with STM32CubeIDE, PuTTY and SerialPlot software.
ii) One STM32F4 board
iii) ONE ST-LINK SWD board



STM32F4 board



ST-Link for downloading and debugging code



SerialPlot's UI

Introduction

In Exercise #2, you would have learned how to read data from the IMU's Accelerometer and gyroscope and have them display in the SerialPort. In the exercises here, you will use the readings from the Accelerometer and Gyroscope to calculate the roll and pitch angles, and observe their characteristics. You will then apply the Sensor Fusion technique to improve the accuracy of the angles by overcoming the limitations of individual sensors.

(Note: The library functions and other related information needed in Exercise #3 are the same as that in Exercise #1 and Exercise #2, and hence will not be re-stated here.)

1. Pitch and Roll Angles

1.1. Pitch and Roll angles from the Accelerometer

(a) Code the routine to access the IMU's Accelerometer. Derive the Pitch and Roll angles by using its appropriate data (as discussed in the lecture). Send the values to the SerialPort program for display. Ascertain that the program is behaving accordingly when you pitch and roll the STM32F4 board at different angles.

(b) Observe the change in the displayed values when you move and shake the board. Add appropriate code to your program to reduce/overcome the effect observed.

1.2 Pitch and Roll Angles from the Gyroscope

(a) Code the routine to access the IMU's Gyroscope and derive the Pitch and Roll angles by using the appropriate approach (as discussed in the lecture). Send the values to the SerialPort program for display. Ascertain that the program is behaving accordingly when you pitch and roll the STM32F4 board at different angles.
(Hint: You may need to use the function `HAL_GetTick();` in your program to calculate the angle)

(b) Move and shake the board and observe its response. Compare it with the response of the Accelerometer under similar conditions. (You can display the angles from both the Accelerometer and Gyroscope on the same screen)

(c) Observe the Gyroscope derived angles while the board remain stationary.

1.3 Pitch and Roll Angles by Sensor Fusion

Sensor Fusion techniques can be used to overcome the limitations displayed by the two individual sensors. For this exercise, you will be implementing the Complementary Filter to perform the Sensor Fusion function, whose equation is as indicated below:

$$\Theta[n] = (1-\alpha) * (\Theta_A[n]) + \alpha * (\Theta[n-1] + \omega_G[n] * \Delta t)$$

where

- Θ can be the Pitch or Roll angles derived based on sensor fusion
- Θ_A is the corresponding angle derived from the Accelerator's outputs values
- ω_G is the rate of change of the corresponding angle output by the gyroscope.
- Δt is the sampling interval.

(a) Code the above equation in your program for Roll (and then Pitch) angle, and compare its performance against those derived from the Accelerometer and Gyroscope.

(b) Change the values of α and observe its effect on the performance.

2. Summary of Exercises

Compare and comment on the accuracy and behavior of the Pitch and Roll angles derived from the Accelerometer, the Gyroscope and the Sensor Fusion respectively.

Explain how you overcome the limitation of their performance.