UNIVERSITY OF LIVERPOOL

Department of Electrical Engineering and Electronics

ELEC230

Robotic Systems – Assignment 2
Sensor Interfacing (25%)

Module	ELEC230
Coursework name	Assignment 2 – Sensor Interfacing
Component weight	25%
Semester	2
HE Level	5
Lab location	EEE PC Labs 304 & 305
Work	Individual
Timetabled time	Semester 1 Labs 11 and (optionally) 12; Semester 2 Labs 1 and 2. Previous labs have also introduced relevant foundational experience.
Suggested private study	30 hours - including lab time.
Assessment method	Individual, formal word-processed reports and .cpp files, as described in the Marking Criteria.
Submission format	Online via CANVAS
Submission deadline	**23:59 on Thursday 17th February 2022**
Late submission	Standard University penalties apply
Resit opportunity	August resit period (if total module failed)
Marking policy	Marked and moderated independently
Anonymous marking	Yes
Feedback	Via comments on CANVAS submission on-line
Learning outcomes	(**BH3**) Knowledge of the capabilities of sensors and actuators used in mobile robots. (**BH2**) Understanding the features of an Object-Oriented Programming language, and the ability to code in C++. (**BH1**) Understanding Linux and the mechanisms provided for multi-tasking.

Marking Criteria

Section	Marks available	Indicative characteristics: Adequate / pass (40%)	Very good / Excellent
Presentation and structure	10%	• Submission includes a Report, plus standalone .cpp file(s) for any code modifications made • Report contains cover page information (with Academic Integrity declaration), table of contents, sections with appropriate headings. • Comprehensible language; punctuation, grammar and spelling are accurate. • Any equations are legible, numbered and presented correctly. • Any verbatim quotes from third-party sources are enclosed in quotation marks and credited with a reference in the IEEE format; third-party images are referenced too. • Third-party ideas are also referenced and are not 'closely paraphrased'.	• Appropriate use of technical, mathematic and academic terminology and conventions. • Word processed with consistent formatting. • Pages numbered, figures and tables are numbered and captioned. • All sections clearly signposted. • Correct cross-referencing (of figures, tables, equations) and fully correct citations by the IEEE standard.
Introduction, Method and Design	20%	• Problem background is introduced clearly • Understanding is shown of the principles and operation of the various sensors	• Excellent understanding of the problem background, explained very well • Excellent understanding of the principles and operation of the various sensors
Results	30%	• Screenshots of relevant work, e.g. program output, are presented for each task • These include the <u>full</u> desktop including the IDE windows and the taskbar with date and time • Screenshots demonstrate the sensors in basic operation • Demonstrators have signed off the basic operation of the sensors	• Screenshots demonstrate successful output for every task, including simultaneous operation of all 4 measurement functions, and enhanced information as instructed • Demonstrators have signed off simultaneous operation of all sensors • Demonstrators have signed off the enhanced functions
Discussion	40%	• Written explanation of relevant aspects of the operation of the sensors is clear and correct • Analysis, including graphs etc., is clear • Written explanation of relevant code (including any code modifications) shows understanding of the relevant syntax and semantics • Supplementary questions are answered to some degree	• Written explanation of the sensor operation is convincing and shows excellent understanding • The analysis is highly convincing, showing excellent understanding • Where relevant, code (including any code modifications) is well-explained and there is evidence of excellent understanding • Supplementary questions are answered very well

ELEC 230 Sensor Interfacing (2021-2022) – 25% weighting

Overview

In the Report for this Assignment you are providing evidence that you have successfully interfaced a range finding sensor and an IMU with a Raspberry Pi Zero W, and showing your ability to do further work with these and your understanding of associated concepts.

Part 1 (50%) Range Finder[1]

1a) In the Semester 1 Week 11 lab (or possibly later) you should have interfaced a VL53L1X-SATEL board with your Raspberry Pi Zero W, and obtained range measurements from 5 drops of a ping pong ball in an acrylic tube. Write up what you did: document parts of the process you judge to be significant, using screenshots (and photos if obtained) to support your writing.

1b) Your data was almost certainly just 5 sequences of range measurements (without time indications). Create a graph of these in Excel – the horizontal axis will just be a sequence (measurement 1,2,3 etc.) rather than showing the measurement time.

1c) Calculate the means of each 'group' of 5 measurements and produce error bars of your data points (use standard error which is standard deviation divided by the square root of the number of measurements used for the mean). To what extent is this meaningful with these experiments?

1d) What is the actual rate of measurement generated by the demo code (measurement frequency)? If you can, modify the code so that the program provides (i) a measurement time with each range measurement, and (ii) an calculation of the measurement rate for each session. (If you have done these two things, provide your modified code as a separate .cpp file, and include some evidence of the modified output in your report.)

1e) You probably tested your work for (d) at home and/or without a ping-pong ball and tube. Write about this, and provide evidence of what you did. Write also about any other questions and points (apart from the below) that you think are significant.

Some further questions and points that should feature in your report:

- Include some theory and background about the laser rangefinder.
- Discuss the interfacing work you did. Why did you connect particular pins? How does the I2C bus work? Why does an I2C bus have the name it has?
- How does the data you obtained compare with the theory in the Week 11 Lab Script? Do some mathematical analysis to compare the two.
- What are the units of measurement in which the readings are given?
- What is the minimum distance at which the rangefinder begins to show a reading?
- Why, in your opinion and based on your research/reading, doesn't the rangefinder show a reading when the object is very close to it?
- In one part of the demo code, a class is created. Explain what each segment of this code achieves. Discuss your understanding of the overall demo code.
- Bonus: alter the demo code to facilitate automatic saving of the generated data in an appropriate format. Again, include evidence of this working, and make sure it features in your submitted .cpp file if you have done this.

[1] Reminder: most of Part 1 was given in the 'Assignment2_initial_guidance' document in December

Part 2 (30%) IMU

2a) In the Semester 2 Week 1 Lab (or later) you should have interfaced a Grove IMU 9DOF (lcm20600+AK09918) with your Raspberry Pi Zero W, and explored the operation of the accelerometer, gyroscope and magnetometer. Write up what you did: document parts of the process you judge to be significant, using screenshots (and photos if obtained) to support your writing.

2b) You should have experimented with the accelerometer, gyroscope and magnetometer in order to develop your understanding of and interpretation of the measurements. Discuss (and provide evidence of) the data you observed – including screenshots – and your interpretation of that data.

Some questions and points that should feature in your report:

- Include some theory and background about the three devices included in the IMU
- What are the units shown for the outputs of the three types of measurement? Discuss the relevance of these units to the purpose of each device.
- Provide evidence of the impact of acceleration in X, Y and Z upon the accelerometer readings
- Why do we need to lie the IMU flat to get ~1000 mg for the Z axis, and ~zero for the other two axes, X and Y? Why are the latter non-zero when not lying flat?
- Provide evidence of the impact of rotation around X, Y and Z upon the gyroscope readings.
- Should the gyroscope read out zero when held stationary but at a non-flat angle?
- How did you use the magnetometer to estimate the direction of North?
- Why does the X reading increase as you 'point' that axis towards the ground?
- (Bonus): you may, additionally, discuss other points you found to be significant.

Part 3 (20%) Supplementary Questions

Some further questions relating to sensors, Linux multi-threading and inter-process communications (IPC) will be placed on Canvas in the week commencing 7/2/22. Please leave space and time to answer these.

How to approach the Report:

Some of what you submit will simply report back on the lab work (and your extra practical work) and your understanding of it; some will require research on Canvas and independent research. Make good use of the documents and resource suggestions already provided on Canvas, but feel free to research more widely, and credit your sources properly.

Structure your overall report by splitting it into Part 1, Part 2 and Part 3, and observe the guidance in the Marking Criteria above about cover page, contents etc. Organise Parts 1 and 2 as implied in the Marking Criteria: 'Introduction, Method & Design', 'Results', and 'Discussion'; not 1a), 1b), 1c) etc. as these letters are just to communicate some objectives clearly to you.

Although an ideal Report would answer every question in this script, and answer it well, you do not necessarily need to answer everything to pass or even to obtain a first-class grade. It is your decision as to how you balance your question coverage against the depth of discussion in each area, but **your Report must not exceed 4,000 words** in its entirety. (Although this doesn't mean that you have to write 4,000 words!) This includes every part of the report document e.g. cover page and references, but does not include the code in any separate .cpp file you submit. The Report word count will be checked using TurnItIn, so please ensure that your file formatting prior to submission does not convert text to image(s).

What to submit

1. A single Report covering Part 1 and Part 2 as described above
2. .cpp file to show the modifications you made (if you did) relevant to Part 1

Also

Make sure a demonstrator has signed off at least your individual connection of each sensor (rangefinder and IMU) and the individual operation of each measurement function (rangefinder, accelerometer/gyroscope, magnetometer). Ideally, show the demonstrator the simultaneous operation of all these measurement functions, across both boards, at once.

Warning

When marking your reports, we will be looking very closely for any signs of collusion, as this is unacceptable. We need to assess your own ability, not that of your friend or colleague. If we find any evidence of collusion or copying then the formal University rules will be followed which may result in your suspension. Similarly, your code, comments and discussion must be your own and not taken from any other source (e.g. online.) If we find evidence that part(s) of your work is/are copied or closely paraphrased from any source then the formal University rules will be followed on plagiarism and collusion, which may result in your suspension or termination of studies.

Submission Information / deadlines

Submit an Electronic copy to CANVAS by: **Thursday 17th February 2022 @ 11:59pm.**

D. G. McIntosh
February 2022