Report Title: Be Descriptive

Student Number Student Number

***Abstract*—It is normal to write the abstract last. First, try to concisely state the problem/question/challenge under investigation. Second, state what you found out. The abstract should help a reader decide if they are interested in reading the whole paper. Keep your abstract short. Don't rely on the abstract to introduce your work.**

I. Introduction

Use the introduction to explain your project (problem/question/challenge) to the reader. To do this well, you will need to provide some background context. It can be useful to imagine you are writing for someone who would be able to understand your work, but who is not familiar with it. You should assume the examiner of this report has **not** seen your project before.

For example, you may need to explain how a sensor works, including the advantages and disadvantages, in order for your reader to properly understand the *value* of your investigation. You want your reader to agree that this is an interesting project, as well as for your reader to understand *why*.

You are encouraged to use specialist language and concepts covered in the unit Robotic Systems to explain the background context of your project. Where this is a piece of educational coursework within post-graduate study, you are not expected to provide a comprehensive literature review. Instead, use citation to assist your communication, and to help make your work reproducible. Where relevant, you are encouraged to reference external sources of information, such as technical datasheets [1] and online articles [2] (e.g. you could reference the unit Labsheets), or academic literature (a conference paper [3], or journal [4]) if it helps with your background context or possible applications.

Adding citations with the correct formatting is easy when you use Bibtex! Have a look at the '.bib' file. You can usually ask a publisher website to give you the bibtex citation format to download, and then copy-and-paste this into the '.bib' file.

Lastly, try to write your report to document the details well and to demonstrate/communicate what was learnt. Because this is a report (not an essay or blog-post) it can be very matter of fact. It is best to avoid "telling a story". If anything, regard this as a type of scientific 'recipe' for someone to fully understand your reasoning and to reproduce your results.

A. Hypothesis Statement

Because you've written a good introduction, and therefore developed an understanding of specialist concepts/language with your reader, you can now write a very specific hypothesis. The hypothesis should exactly describe the aspect of the system you are investigating. Avoid a statement that is general or self-evidently true. For an example of a weak hypothesis: *"By making the system better, we will measure an improvement."* - this doesn't help us to understand what would be learnt through this hypothesis.

Because formulating a hypothesis is central to this assessment, it is recommended you write your hypothesis into a clear subsection (this subsection) as specified in this report template. Sometimes, you might find you have more than one hypothesis that has guided your investigation. You may have a general hypothesis, and then progressed the work further with a more specific hypothesis. You can state both and then instruct the reader that these are then reflected in your Experiment Method (section III). Here is an example of a hypothesis:

> *Because the VL1680X has been identified as an active sensor with ... limitations, we hypothesise that: by applying ... filtering to the sensor we could negate ..., and so predict a measurable improvement of the sensor when varying ... conditions.*

The rest of this report proceeds as follows: Section II describes the system we have design and used. *You should complete this brief description of your report structure.*

II. Implementation

In this section you should describe the specifics for your implementation such that your reader could recreate your work. If you have used a well understood algorithm or technology you can reference an external source, unless explaining the algorithm/technology provides vital information for the reader regarding your project. You may wish to present technical information or preliminary results (e.g. a plot of a sensor response) to support the understanding of a specific component. If you are going to compare your robotic system against itself then you may need to document your "baseline" solution and your "improved" solution.

It can be a good idea to include pseudocode (see Algorithm 1), and you may also want to include equations in a clear format such as eq.1.

$$E = mc^2 \tag{1}$$

If it helps to communicate, consider a block diagram to communicate the architecture of your robotic system (such as the flow of information between system components), a flow-chart to describe a sequence of events or behaviours, or something like a state-diagram to describe your robot controller/behaviours. Rather than attempt to use all of these, consider which are most important to include to provide sufficent detail to allow your work to be reproduced.

Remember that, to design an experiment - and therefore to identify the experiment variables - we first have to fully understand what system we have built. The experiment variables come out of the system we have built and used.

Algorithm 1 Collect & Report Samples

```
Input:
Output: Array of sensor readings, R

MaxSamples ← 10
for i ← 0 to MaxSamples do                ▷ Collect Samples
    do Algorithm 1
    R[i] ← t_elapsed
    delay(200)
end for

while true do                             ▷ Report Results
    Serial.println( "Results:" )
    for i ← 0 to MaxSamples do
        Serial.println( R[i] )
    end for
    delay(1000)
end while
```

III. Experiment Methodology

In this section, document how you designed your experiment method. We can think of the experiment method as the processes followed to take measurements from your system, where you will vary only 1 variable (in an ideal experiment) to observe the effect. The *experiment method* is the structuring or configuring of the system, parameters, task and environment. Relative to this, an *experiment procedure* details the steps a human must take to conduct the experiment, if this may have consequence (for example, how is the robot placed by a human in the start position to ensure this is consistent and repeatable?).

The Experiment Methodology section should be clear and concise - and you can achieve this by first providing a detailed Implementation section so that those elements do not need to be restated here. If we understand how your system was implemented (built, made), then in this section we just need to know what part was measured and how. Again, it is important that you provide enough detail so that someone could reproduce your work.

Having a well detailed implementation and experiment method will mean that we can better understand what has influenced your results. A good experiment methodology would mean that the reader can already understand what results you are likely to produce before they have even looked at your results section.

You also want your reader to agree that you carefully considered your experiment so that we could trust your results to be both *insightful* (mean something) and *credible* (not subject to error). A common mistake by many students in this area is to only run 3 repeated trials. Think about this - if we have only 3 data points, it is impossible to know if one of them was an outlier. A common questions is "how many repeated trials should I make?". The answer is that the number of trials should mitigate the expected variance in your results. As a general rule - capture 10 repeats, plot and review your results, and then decide if you need a higher number of repeated trials.

The following subsections are suggestions to aid the clarity of your work.

A. *Overview of Method*

Describe to the reader the general structure and procedure of your experiment. You should provide a specification a bit like a cake recipe. For example: how long does your experiment last? how many repeated trials do you use? how many alternate scenarios are there?

B. *Discussion of Variables*

You should outline the key variables within your experiment. This will help your reader to later believe your results are credible and not confused (confused means, too many things changing at once).

- **Controlled Variables**: These are the parts of your experiment (task, hardware, software, environment) which *could* vary, but which you have controlled by careful design of your experiment. For example, battery life varies, so you will use new batteries.
- **Independent Variable**: This is the part of your experiment which you are changing so that you hope to observe a measurable alteration in performance. Note that, we ever only want one independent variable - sometimes we aim for this, but concede other parts will change, and we need to make careful analysis of our system, method and/or results.
- **Dependent Variable(s)**: These are the part(s) of your experiment in which you hope to observe a measurable change. You will design or select appropriate *metrics* to measure and analyse this dependable variable. For example, we can have one dependent variable of the system (e.g., sensor readings), but design metrics to calculate and present aspects like: what proportion were positive, negative, and a mean of the absolute values.

C. *Discussion of Metric(s)*

In this section you should discuss the rationale (why) you have selected your metric(s) - e.g. how do these metrics help us to interpret your results? A good way to think about a metric is that it can give context to your results. For example, only looking at the proportion of positive values might be discussed as the *overshoot* of the system - but this will only make sense within the context (task) of your system. Your metric(s) will need to be applied consistently throughout your experiment for them to provide a comparison of performance.

You should discuss the advantages and disadvantages of your metric(s). Often, we need more than one metric to compensate for the information which is confused or hidden in another metric. By using more than one metric, we can get closer to the truth of the outcome of your experiment, or gain deeper insight.

IV. Results

In this section you should present your results. How to report and discuss results varies within each discipline. In general, use the Results section to provide a focused, high-detail analysis/observation of your system. Later, use the Conclusion section to discuss the broader, more general implications of your results and study.

You can find help and advice on plotting high quality graphs via Python and Google Colab at the link provided for this reference: [5].

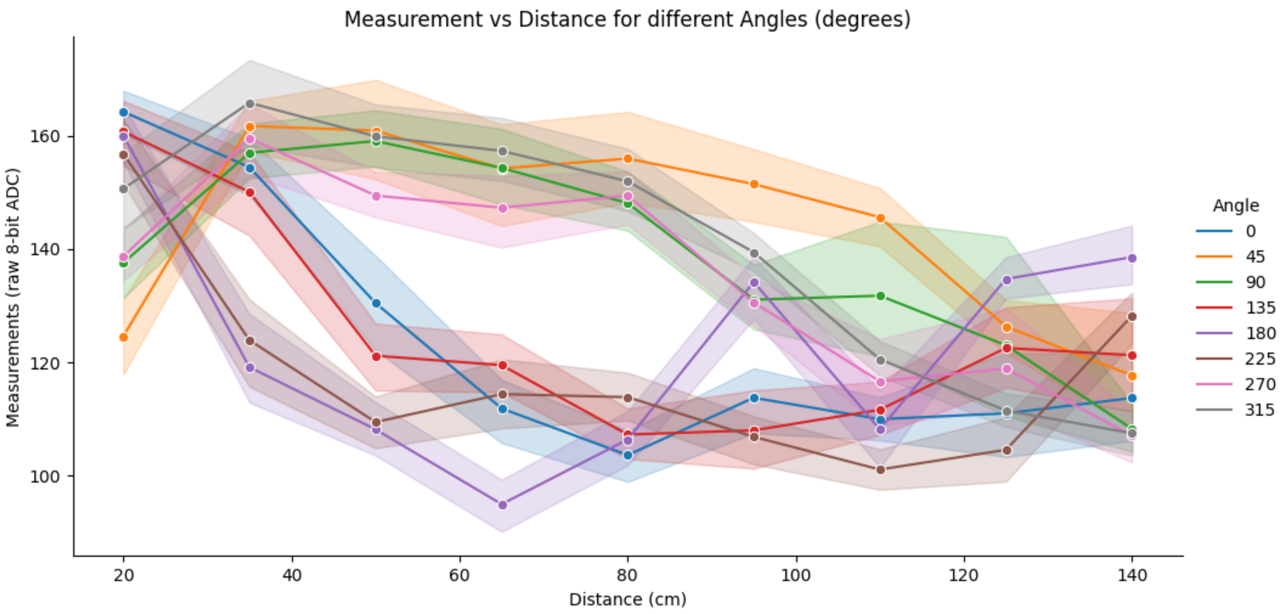

Fig. 1. Use the caption to give the context of the plot to the reader.

In general, it is best to aim for both *quantitative* results (e.g., lots of data collated together and presented for comparison) and *qualitative* results (e.g., a plot of data from a single trial, a written observation or a graphic produced from data which is representative). As a general rule, *quantitative* results provide greater evidence, more information and better confidence in your work.

You should use subsections where they aid in clarity. Usually, if you have described experiment scenarios in your Experiment Method (section III), we would see the structure reflected (repeated) here again in the results. For instance, it may be useful to present results for a "baseline" system, then results for an "improved" system, and then finally results which consider both "baseline" and "improved" systems together. However, avoid repetition - try to ensure a graph or figure is explicitly discussed and therefore has purpose. However, this will depend on your project, how you have designed your experiment, and some thought on the best communication of the results.

When presenting results, aim for a presentation which clearly communicates an insight. Avoid making the reader do extra work - for example, if you are going to compare two results, put them on the same plot. Avoid a need for the reader to make their own interpretation - instead, write guidance on what to observe, how/where, and what it means - and do this by referencing your figures. For example, in figure 2 we can observe a single outlier at *distance=35*, which is believed to have occurred because... (you would write your understanding here).

For example, a large table of all the individual data requires the reader to do a lot of work to find out what is important. It is also difficult to spot outliers or patterns in a table of numbers. Statistics are important, but they can also be misleading (see this great example on Wikipedia [2]). Therefore, the better communication of results are typically visual plots.

Because you have designed a robust experimental method that has many repeated trials, you will almost

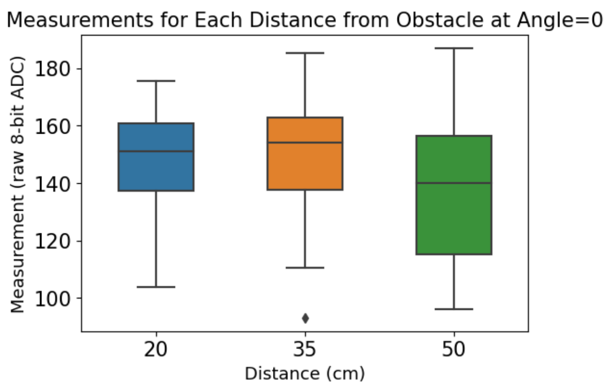

Fig. 2. Use the caption to give the context of the plot to the reader.

always want to plot the distribution of your results. This gives the reader confidence that you have done repeated trials, and we can learn about how reliable the performance was (etc). We can see that in figure 1 the distribution is represented as a shaded region (a confidence interval of 95%) and figure 2 is a boxplot with whiskers.

Remember to label all axis, caption all graphs, figures and tables, and to reference these elements in the report text (e.g. see figure 1) - never require a reader to have to come to their own conclusion or understanding, explain what they are looking at. Remember to attempt to give an explanation for any anomalies in your results.

V. Discussion and Conclusion

Begin your discussion and conclusion by re-stating your hypothesis. You can literally copy-and-paste your hypothesis here.

> *Because the VL1680X has been identified as an active sensor with ... limitations, we hypothesise that: by applying ... filtering to the sensor we could negate ..., and so predict a measurable improvement of the sensor when varying ... conditions.*

Make a discussion of what your results showed - whether this supported or refuted your hypothesis. Try not to respond to your hypothesis as if you were right or wrong, or successful or unsuccessful. Instead, evaluate your hypothesis for whether it helped you to learn something - was it a good question or prediction to make? Was it useful in this way? If not, in what way does the hypothesis need adjustment, to guide future experiments?

Remember that you can again reference back to your own figures or subsections for clarity. It may be that the results were mixed (supporting and refuting) and you should discuss that here. In your discussion, use this as another opportunity to demonstrate/evidence your understanding. Try to avoid stating the obvious - instead, use analysis/evaluation/synthesis to show that you understand *how* and *why* you saw the results you did.

Use the Conclusion section to discuss the implications of your study. This should therefore link back to your introduction, which began with a broad statement of the problem area. Now, with your results providing evidence, you could attempt to make recommendations for applications in this area or for future studies.

This is also a good opportunity to evaluate your experiment and project as a whole. You may wish to further discuss the limitations of the study (e.g. the difficulty of controlled/dependent variables, or any problems you faced in your project). When you did discover limitations in your method, use this to illustrate that you understand the issue by detailing how it could be rectified in future work. When making a recommendation for future work ensure that this is a clear advancement from the understanding you have gained and not wild speculation. It is not useful to see future work like “I would use a high resolution doppler radar instead” - because this doesn’t improve our understanding of your reported work, or how your work could be advanced in a meaningful way.

Finally - it is not necessary to strictly adhere to this template. Please use your supervision meetings to discuss the best structure and communication of your work as it develops!

References

[1] M. T. Atmel Corporation, “Atmega88-atmega168 datasheet,” 2016. https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-9365-Automotive-Microcontrollers-ATmega88-ATmega168$_Datasheet.pdf, [Accessed21-09-2023]$.

[2] Wikipedia, “Anscombes quartet – Wikipedia, the free encyclopedia,” 2023. https://en.m.wikipedia.org/wiki/Anscombe21-09-2023].

[3] J. Langston, K. Schoder, M. Sloderbeck, M. Steurer, and A. Rockhill, “Testing operation and coordination of dc solid state circuit breakers,” in *IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society*, pp. 3445–3452, 2018.

[4] L. Bayindir, “A review of swarm robotics tasks,” *Neurocomputing*, vol. 172, no. 8, pp. 292–321, 2016.

[5] P. O’Dowd, “Plotting guidance,” 2023. https://github.com/paulodowd/PlottingGuidance, [Accessed 21-09-2023].