

proposal

by Matthew Taylor

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University of Wales
Trinity Saint David

Design of a Pollution Monitoring Station

Proposal

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ABSTRACT

In this proposal I have performed a literature review of current sensors and pollution monitoring stations. I found a very limited market of pollution monitoring stations at a low price point. I found a range of sensors that are suitable for this purpose and studies that have researched the practicality of using low-cost sensors for this purpose. I found that national organisations like the Europeans Union's Joint Research Centre and the USA's Environmental Protection Agency are both using low cost sensors in their projects.

I have also summarised the key parts of the product that I am designing, my objectives and my plan.

INTRODUCTION

There is a pressing reason for the need for pollution monitoring to become more readily available at a more affordable price point. People's health is adversely affected by pollution, increasing peoples risk to health complications and is even attributed to a sizable number of deaths in the UK and worldwide each year.

I propose to design a pollution monitoring station, using low-cost sensors. There is an increasing discussion about the viability of using low-cost sensors instead of reference method devices, due to the large price discrepancy between the two. My original intention for the product was that it could have a place in the museum and heritage sector, where I currently work. I could see museums with outdoor aspects or heritage site with large outdoor estates having an interest in the conditions of their environment. During my literature review I found that there is a market demand for low-cost sensors for citizen science.

In this proposal I have discussed some previous writings on the topic, to determine the viability of my proposed product. I found that there will be limitations on the conditions in which the product will work, and I will need to additionally monitor the conditions of temperature and relative humidity, to know when the unit can accurately record data. I also found that the sensors accuracy could be limited to a year without further calibration.

LITERATURE REVIEW

Around 40,000 deaths are attributable to exposure to outdoor air pollution in the UK in 2016 [1] and ambient pollution was shown to be detrimental to people's health, with particulate matter causing the death of over 3 million people worldwide in 2010. [2]

Venkatraman Jagatha and her co-authors [3] wrote a review into low-cost pollution sensors and highlighted that the current spatial measurements of outdoor air pollution is limited by the high cost of reference devices. She argues that there is a paradigm shift towards using low cost sensors due to the high price as well as advancements in micro-sensing technologies. She points to Purple-Air a company who manufacture low-cost sensors working together with the Environmental Protection Agency of the USA (EPA) in its projects[4]; and the draft roadmap of the EPA's next generation of air quality monitoring includes low-cost sensors. In Germany, Breeze Technologies works on projects together with different state governments within their projects[5], and Sense-Box project, supported by the German Federal Ministry of Education and Research. Expanding to the European Union, the Joint Research Centre (JRC) "welcomes the frequent use of low-cost sensors by citizens, researchers, and institutions despite their drawbacks." [3] The JRC used low-cost sensors in their AirSenseEUR project and are testing low-cost sensors to classify them according to their probable applications[6].

The accuracy of low-cost sensors has been called into question by many international and national bodies, resulting in guidance on where low-cost sensors are appropriate and methods of improving the quality of their data. Specifically, the longevity of low-cost sensors is of concern because they can lose accuracy from when they were originally calibrated. Reference devices will be re-calibrated on a routine basis, but low-cost sensor won't necessarily get the same treatment as calibration is expensive and opposes the original argument of low-cost sensors.

Jiří Bílek and his co-Arthurs [7] ran a study for over 2 years near an Ironworks in the Czech Republic, using a network of PM_x, NO₂ and ozone sensors to evaluate the use of low-cost optical and electrochemical sensors over a continuous year-long operation. They found that the PM_x measurements corresponded well with the reference method, and that the sensor they used, the Alphasense OPC-N3, could be used accurately individually or as part of a cluster. They found that the NO₂ 's sensory measurements were poor when using linear regression methods, although the data could be improved with corrective functions, and more advanced data analysis methods.

The authors concluded that the sensors are not suitable replacements for reference method devices, but are suitable for monitoring trends and concentration, and when deployed in a cluster have a high spatial and temporal resolution. They also concluded that they had proved the long term usability with their annual measurements.

I will measure Particulate matter smaller than 2.5 μm as it is a good proxy for overall pollution levels, including ambient particulate matter pollution from transportation, wind-blown dust, burning of biomass, and industrial sources. [2]

I will also track temperate and relative humidity, as these variables can affect the efficacy of the sensor, and if either of these variables go out of sensors range of operation, then the data needs to be disregarded during those events.

I found three low-cost pollution monitoring stations currently on the market. Gaia produce their A12 station [8] which is the cheapest I found at £174 and ships from China. It measures PM1.0, PM2.5 and PM10, as well as temperature, relative humidity. PurpleAir sell their PA-II-FLEX [9] for £260.31 from the US which monitors 0.3, 0.5, 1.0, 2.5, 5.0, and 10 μm particulate as well as temperature, humidity and pressure. Aeroqual based in the UK offer their AQY R [10] which measures the greatest range of pollutants, measuring PM2.5, PM10, as well as gaseous pollutants ozone (O3) and nitrogen dioxide (NO2). It also measures temperature, relative humidity, and the dew point.

I have researched a range of sensors and placed them in table (1). I recorded the size of particulates they can measure, their power consumption when active and when in standby, the environmental conditions they can operate in and how they output their data. In the final report I will choose an appropriate sensor. The initial specifications look viable for the product. Importantly they all have a low power requirement which is important as they will be situated outdoors any may have to run off solar power and/or a battery. They are also suitable for a large range of temperatures and relative humidity, so readings are unlikely needed to be paused. All these sensors are self-aspirated which will have to be factored into in the design in the enclosure.

manufacturer	model	size of particulate	power	operating temperature	relative humidity	data output
Alphasense	OPC-N3 sensor	0.35 μm to 40 μm	5v, 0.9w, 0.2w standby	-10 to 50°C	0-95%	SPI
Alphasense	OPC-R2 sensor	0.30 μm to 12.4 μm	5v, 0.55w, 0.03w standby	-10 to 40°C	0-95%	SPI
Honeywell	HPMA115S0-XXX	2.5 μm or 10 μm	5v, 0.4w, 0.1w standby	-10 to 50°C	0-95%	UART
Winsen	ZH03B	2.5 μm	5v, 0.6w, 0.1w standby	-10 to 50°C	0-95%	UART or PWM
Winsen	ZPH01	2.5 μm and VOC	5v, 0.75w, 0.1w standby	-10 to 50°C	0-95%	UART or PWM
Plantower	PMS-6003	0.3 μm to 10 μm	5v, 0.5w, negligible standby	-10 to 60°C	0-99%	UART

Table 1 - PM sensors

AIMS AND OBJECTIVES

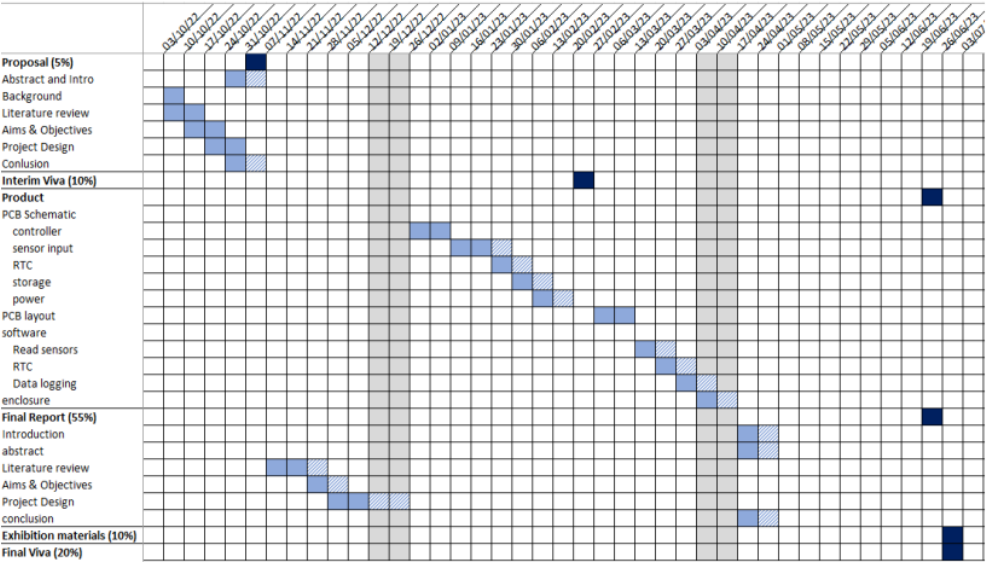
My aim is to design a pollution monitoring Station, including the PCB, the software, and its enclosure.

- I will research the viability of low-cost sensors, and if they would be appropriate for my product.
- This will include their accuracy and their longevity without further calibration.
- Discuss the reasoning for designing such a product, its use case and it’s limitations.

I will deliver a prototype of the pollution monitoring station, including a PCB. To keep the price of the prototype down, I will use cheaper variations of the chosen sensors, and I will also 3D print the enclosure. I will produce a PCB schematic and PCB layout in the course of making the prototype. I will also be delivering the software running on the hardware.

PROJECT DESIGN

I am loosely following the feature driven design framework. I have planned out the project, breaking it down into smaller tasks. I have also created subtasks for the first set of tasks. I have drawn out a Gantt chart to keep track of my progress through the project, including important deadlines. I planned for a 20% time contingency for each task.



Evaluating the credibility of my proposal. I suggest that the reliability of the data gathered by my device should be reliable and would provide equally accurate results if the measurements were taken by a different person, presuming that the environmental conditions are within the specified ranges, and within a year of the device's calibration.

One way of seeing validity of the product would be seen in its commercial success. I propose the product has the potential to be a viable competitor to the products already on the market, and I am uniquely positioned to make this available to the museum and heritage sector.

The results from an individual unit is hyper-local to the area it's placed at. The product itself has a greater generalisability as it could be a useful device from small to medium sized heritage sites, and outdoor museums.

CONCLUSION

In conclusion I think the project is achievable and I should be successful in delivering the proposed product. My initial concerns that the accuracy of the station would be low when using low-cost sensors was challenged by Jiří Bílek and his co-Arthur's work in testing low-cost sensors over a two-year period, as well as Venkatraman Jagatha and her co-authors work in researching projects that have already deployed low-cost sensors.

- [1] 'Every breath we take: the lifelong impact of air pollution', *RCP London*, Feb. 23, 2016. <https://www.rcplondon.ac.uk/projects/outputs/every-breath-we-take-lifelong-impact-air-pollution> (accessed Oct. 30, 2022).
- [2] S. S. Lim *et al.*, 'A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010', *The Lancet*, vol. 380, no. 9859, pp. 2224–2260, Dec. 2012, doi: 10.1016/S0140-6736(12)61766-8.
- [3] J. Venkatraman Jagatha *et al.*, 'Calibration Method for Particulate Matter Low-Cost Sensors Used in Ambient Air Quality Monitoring and Research', *Sensors*, vol. 21, no. 12, p. 3960, Jun. 2021, doi: 10.3390/s21123960.
- [4] Karoline Johnson, Brett Gantt, Ian VonWald, and Andrea L. Clements, 'PurpleAir PM2.5 performance across the U.S.#2'. https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=CEMM&dirEntryId=348236 (accessed Nov. 06, 2022).
- [5] 'Urbane Luftqualitätsüberwachung: Luftqualitätssensoren, -daten und -analysen', *Breeze Technologies*. <https://www.breeze-technologies.de/de/loesungen/urbane-luftqualitaet/> (accessed Nov. 06, 2022).
- [6] M. Gerboles, L. Spinelle, and M. Signorini, 'AirSensEUR: an open data/software/hardware multi-sensor platform for air quality monitoring. Part A: sensor shield', *JRC Publications Repository*, Oct. 21, 2015. <https://publications.jrc.ec.europa.eu/repository/handle/JRC97581> (accessed Nov. 06, 2022).
- [7] J. Bílek, O. Bílek, P. Maršolek, and P. Buček, 'Ambient air quality measurement with low-cost optical and electrochemical sensors: An evaluation of continuous year-long operation', Accessed: Oct. 24, 2022. [Online]. Available: https://core.ac.uk/display/511369884?source=1&algorithmId=15&similarToDoc=479348507&similarToDocKey=CORE&recSetID=d8622bb0-10db-4e3b-9867-15cbe6c2cb36&position=3&recommendation_type=same_repo&otherRecs=233231461,323987413,511369884,210998804,196584653
- [8] T. W. A. Q. I. project, 'Chất lượng không khí trên toàn thế giới: AirNet Sensor Network', *aqicn.org*. <https://aqicn.org/gaia/> (accessed Nov. 09, 2022).
- [9] 'PurpleAir PA-II-FLEX Air Quality Monitor', *PurpleAir, Inc.* <https://www2.purpleair.com/products/purpleair-pa-ii-flex> (accessed Nov. 09, 2022).
- [10] 'Portable Air Quality Network Monitor - AQY R'. <https://www.aeroqual.com/products/aqy-r-series> (accessed Nov. 09, 2022).

FINAL GRADE

GENERAL COMMENTS

Instructor

74/100

Intro / A&O (400 words)		
Project title; Identification of a specific problem to be investigated; Well-defined aims and SMART objectives; Explaining why this project is worth doing; Discussion of what the project needs to do in order to be a success; Description any deliverables that will be produced at the end of the project	20	15
Well defined objectives, very good description of why the project is worth doing. Good description of deliverables		
Background to the Project / Literature Review (400 words)		
Description of how the work to be done by in the project relates to the work identified in the literature review; Discussion of any ethical issues raised by the project Identifying what has already been done within the field; Topic familiarity; Brief literature review using appropriate sources – 6-8 journal papers and book chapters rather than just websites;	20	15

Selection of relevant models & concepts		
Good background to the project and excellent range of references.		
Project Design (500 words)		
Clear statement of which development methods are to be used and why they are appropriate; Clear statement of which tools are to be used and why they are appropriate; Clear description of how data collected will be analysed		
Good description of the methods to be used and which tools will be used.	30	20
Resources / Planning (200 words)		
List of any deliverables; Clear diagram showing both timing and resource use; Completed ethics form; Limited and relevant appendices	15	12

Clear list of deliverables and Gantt chart showing timings of individual tasks. Good to see contingency time added to project plan.		
Document Presentation		
Correct spelling, grammar and punctuation; Flow of narrative/fluency; Coherence; Word processed ; Correct use of referencing with bibliography; Strict word limit Well presented, coherent report.	15	12
TOTAL	100	74

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