ENGINEERING

McMaster University

Source Water Monitoring Project

Final Report

ENGINEER 2PX3 – Integrated Engineering Design Project

Tutorial 10

Water 21

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Executive Summary

Climate change is significantly impacting the quality of drinking water sources through floods, wildfires, and harmful algal blooms. One of the biggest challenges faced by drinking water treatment plants is sudden changes to source water quality. When this happens, the plant must quickly adapt its treatment process. As such, early detection of changes in source water quality is critical in the protection of human health. [1]. This team was tasked with creating a system that monitors the progression of the algae blooms in a lake for the source water treatment plant to keep the community safe. The final system was developed and optimized over three design iterations. The first design was a performance-focused drone, the DJI MAVIC. The second design iteration is a performance and socio-cultural-focused drone, the EACHINE wizard E220. The third and final design iteration considered all PERSEID layers while maximizing the performance of the overall system. The final design was decided to be using an Autel Robotics EVO II drone. The final design utilizes a dual neural network that uses a conditional verification system. The deep and convolutional machine learning models are trained on 10,000 image databases and produce accurate results. The final flight path consists of three drone charging stations evenly distributed along the lake's shore.

The final design boasts many advantages over previous iterations. The final design aligns with stakeholders' needs, considers all PERSEID layers, and is optimized for the greatest performance. Moving forward, our team will host stakeholder meetings to refine elements of the design. The meetings will discuss the environmental and socio-cultural solutions that were developed. We will gather opinions on the system via surveys. The meetings will determine how the stakeholders feel about the design and provide feedback to improve the design. There will also be meetings with the Canadian Aviation Transport Canada's Civil Aviation (TCCA) Directorate. The TCCA will oversee the implementation of the system in source water regions to verify that the system is in accordance with Canadian aviation laws. In the future, the project will track the performance of the system by keeping performance indicating statistics and use these statistics to refine the performance aspects of the system.

Introduction

Harmful algal blooms have been ever more present in many open bodies of water due to the impact of climate change. In the summer months, the water temperatures are ideal for algae to thrive and emit toxins into the water. The management of algal blooms are key to maintaining a safe supply of drinking water for the communities. The task at hand for the project is to create a system that monitors the progression of the algae blooms in the lake for the source water treatment plant to keep the community safe [2].

The key project stakeholders for the source water monitoring project include: the water treatment plant, the general community, the lakeshore residents, environmentalists, and the government [3]. The water treatment plant values a system that performs well and detects algae effectively, while the general community wants to remain safe and healthy. The lakeshore residents also want to remain healthy, but without major disruptions to their local community. Finally, the environmentalists and the government want to confirm that the environment and laws are being considered in the design process. Each stakeholder values different aspects of the project, which leads to stakeholder conflict.

To account of the complex and multi-layered objectives, constraints, and conflicts in the source water monitoring system, the PERSEID framework is used. This method of design iteration allows each different stakeholder viewpoint to be analyzed with different constraint lenses, which are Performance, Environmental, Regulatory, and Socio-Cultural. The funnel-like approach to problem solving lets each of the constraints be evaluated individually, then combined into an iterative and ongoing design solution [2].

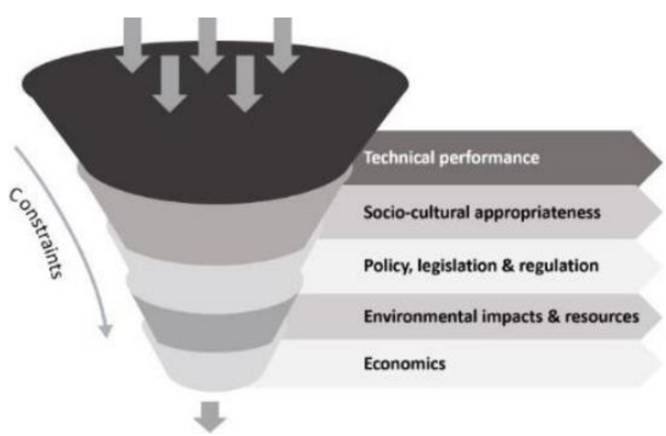

Figure 1: PERSEID Funnel Framework [3].

The chosen lake to monitor is Lake St. Clair, which is located between Lake Huron and Lake Erie and is divided by the US-Canada border. The south Canadian shore is the most likely location for algae to bloom in Lake St. Clair, which is where the operation will focus. There are two large cities near the lake – Detroit and Windsor – that have a large population that could be affected by the presence of algal blooms. On top of large cities, the entire southern shore contains beaches and homes, which adds to the amount of people possibly affected. The north-eastern shore is part of a protected area, and with the lower abundance of algal blooms, makes operating on the north-eastern shore not practical. The large majority of the monitoring system will focus on the southern shore of Lake St. Clair where algal blooms are often present.

Figure 2: Lake St. Clair with Present Algal Blooms [4].

The approach taken to solve the problem is to use a camera mounted onto a drone that flies above the lake to survey the formation of algal blooms. The drone will fly on a set flightpath that covers the majority of the shore of Lake St. Clair and capture many images of the water. The images taken by the drone system will then be sent to a neural network algorithm that has been trained to detect the levels of algae present, and when a threshold is reached, the appropriate people will be notified to investigate [2].

The drone water monitoring project will only be focusing on the design of the system and how different designs have different benefits to stakeholders. The project will not be focusing on the economics or physical implementation of the system but does consider the impact of a given design across many points-of-view, mainly the overall performance and the environmental, regulatory, and socio-cultural constraints.

Conceptual Design

Overview of PERSEID Layers

Our final design was developed via the PERSEID method, which includes performance, environmental, regulatory, and socio-cultural considerations. The main focus was to maximize the performance layer. The performance layer considers how accurately the system can predict if the lake contains algae. To accomplish this, there was priority for a longer battery life, greater flight stability, high image quality, and a dual neural network. We then considered the regulatory layer, The Regulatory layer embodies policy, legislation, and regulatory constraints. To conform with government policies, the design had to optimize the flight path of the drone system so that it does not interfere with airports, residential areas, reserves, and environmentally sensitive areas. The third layer considered was the socio-cultural layer. The socio-cultural layer is the impact of the system on social and cultural factors and prioritized three design impacts to mitigate: noise disturbance, privacy concerns, and potential damage. To alleviate these concerns, the design implemented larger propellers, avoiding residential areas, and avoiding environmentally sensitive regions respectively. Lastly, we considered the environmental impact. The environmental layer considers the system's environmental impact and to reduce overall environmental harm, a drone with materials that are biodegradable was decided on.

First Design Iteration

Based off the performance layer of the PERSEID method, the overall design was to create a low-height aerial monitoring system with the following well-considered criteria: Flight stability and battery life being the highest priorities, followed by image quality. These characteristics serve vital importance for the entire system to operate with high accuracy and operational efficiency.

Using the first decision matrix in Appendix A, the drone model selected for this design iteration that meets these attributes is the DJI Mavic Air 2S, offering a battery life of 25 minutes, weight of 4259 grams, a max speed of 94 kph, and an image resolution of 20 MP [5].

With regards to the algae identification processes, the design iteration uses a hybrid combination of two machine learning models. The algorithm will be trained on a large sample size, using two different neural network structures, Deep Neural Network and Convolutional Neural Network. The first algorithm minimizes false negatives and the second minimizes false positives of algae detections. For improved accuracy they will check the outputted results against each other, if either algorithm outputs a positive detect, the lake will be manually checked. A possible flightpath configuration that is achievable is shown in Figure 9 of Appendix B.

Strengths	Weaknesses
Battery Life: This drone uses the battery life efficiently **False Non-Detects:** Minimizes amount of false detects and best helps the environment **Flight Stability:** Highest wind resistance and stabilizes drone for more accurate captures/images. Can navigate through harsh weathers. **High Image Quality:** Uses powerful camera (larger weight) and captures accurate images	**High Noise Pollution:** Has high noise pollution and is distracting. **Not Environmentally Friendly:** Uses harmful material **High Maintenance:** This drone would use much more expensive material and equipment so if it were to crash, it would cost more. **Requires License:** If the drone surpasses a 250g, it requires a license

Table 1: ***Table Representation of First Design Iteration's Strengths and Weaknesses***

Second Design Iteration

In view of socio-cultural constraints, the design had to be adjusted, so the second design iteration aims to minimize privacy concerns, noise pollution, and injuries or property damages. Drone speed and flight duration contribute to noise pollution, the image quality adds to the privacy concerns of the stakeholders, and the drone speed and weight contribute to the potential to cause injuries and property damages.

Using the second decision matrix in Appendix A, the selected drone is the EACHINE Wizard X220, offering a battery life of 15 minutes, weight of 535 grams, a max speed of 115 kph, and an image resolution of 16 MP [5]. This 2nd design iteration also employs the hybrid combination of the and Neural Network machine learning models, which reduces the false negative and false positive algae detections.

The most important aspects of the socio-cultural concerns will be noise pollution, privacy, and accidents that may lead to injuries or property damages. For noise pollution, it was decided to operate at far enough distances and altitudes, and also possible use of active and passive noise filtering technology; however, these may have the adverse effect of increasing power consumption and the weight of the drone.

For privacy concerns, all images captured by the drone will be filtered through an additional machine learning algorithm that will detect if there are people in the images, if so, their faces will be blurred. Another aspect of privacy concerns to take into consideration is hacking of the drone monitoring system for spying purposes. In light of this, the drone system will employ cyber security measures to ensure that the system is safe from cyber attacks.

Accidental injuries and property damages will be minimized by chartering flightpaths that avoid populated areas, as seen in Figure 10 in Appendix B. Another goal is to be able to rate the performance of our drone monitoring system in terms of its socio-cultural impacts on the local communities in which we will be operational. To do this, a monthly automated survey can be employed in which the stakeholders will be able to rate the performance of the system in terms of privacy, noise pollution, and accidents from the drone system.

Strengths	**Weaknesses**
False Non-Detects: Minimizes amount of false detects and best helps the environment **Noise Filtering:** There will be a less amount of noise generated by this drone as it has a noise filtering system and is a lower weight. **Highly developed Security System:** The algorithm will be more likely to prevent any cyber attacks	**Not Environmentally Friendly:** Uses harmful material for the environment **Battery Life:** Does not use battery life efficiently. **Image Quality:** The image quality is not as high as the performance-based drone

Table 2: ***Table Representation of Second Design Iteration's Strengths and Weaknesses***

Third Design Iteration

The third iterative design carries a few features from its predecessors but also includes new features that account for regulatory and environmental concerns. The main regulatory concerns that this design accounts for include, operating 30 m away from bystanders and above any buildings or structures. Operating 5.6 kilometers from airports and avoiding restricted airspaces and borders. The main environmental concerns that this design must account for include, noise pollution, environmental pollution, and environmentally sensitive areas.

To meet the environmental and regulatory constraints, the drone must have less speed and weight to minimize the potential for injuries and property damages, and it must have a longer battery life or clean energy storage alternatives to minimize environmental pollution. As seen in Appendix A, the drone that selected to base the third design iteration is the Autel Robotics EVO II, which has a battery life of 40 minutes, a weight of 1174 grams, max speed of 72 kph, and an image resolution of 48 MP [5]. To adhere more closely to environmental concerns, changes are made to the drone to make it environmentally friendly. For example, the materials used to construct the drone can be made from bio-degradable plastics or plastic-alternatives such as protein and carbohydrate-based polymers made from algae. The batteries used by the drones must be safe and allow for safe disposal, so rechargeable batteries are favourable.

In terms of algae detection capabilities, the third design iteration also employs a hybrid combination of the Deep and Convolutional Neural Network machine learning models, reducing false negative and false positive algae detections. In terms of socio-cultural considerations, the third design iteration employs high operational altitudes, and passive/active noise filtering technologies to address noise pollution. It employs a face blurring machine learning algorithm as well as robust cybersecurity measures to prevent hacking.

To account for regulatory constraints and environmental concerns, the navigations and flightpath chartering system of the drone monitoring system will need to be able to identify borders, airports, restricted airspaces, populated areas, and environmentally sensitive areas. Because the drones have larger batteries the system can rely on less landing stations, which mitigates environmental impacts. An example of a flight path that might be generated in the third design iteration is shown in Figure 11 of Appendix B.

To comply with regulations and prevent damages and injuries to people or property, the drones will need to be able to detect obstacles and operate 30 m away from them. Ultrasonic sensors and image recognition software can be implemented into the drone monitoring system to enable it to identify the various types of obstacles and make smart decisions.

Strengths	Weaknesses
Battery Life: This drone uses the battery life efficiently and has a large battery lifetime **False Non-Detects:** Minimizes amount of false detects and best helps the environment **Minimized Drone Stations:** This drone allows the team to use a low amount of drone stations for the flight path **Environmentally Friendly Material:** This drone uses material that is not as harmful as materials used in the pervious drones **Image Quality:** High image quality	**Drone Speed:** The drone speed is average; however, it will take longer than the first iteration to run through its pathway **Flight Stability:** Drone is lightweight, which affects the flight stability negatively

*Table 3: **Table Representation of Third Design Iteration's Strengths and Weaknesses***

Options for Neural Networks

When looking at the neural network options for the source water monitoring system, there are three main options: a deep neural network which has a low false positive rate, a convolutional neural network which has a low false negative rate, and a recurrent neural network which has a balance of both rates. Because the time and costs of training each of the neural networks are out of the scope of the project, the algorithms with the largest training dataset, which are the most accurate algorithms, should be used. When combining algorithms, the false positive and negative rates can change depending on whether a positive outcome is determined by if both or either algorithm is outputting positive. The false positive and negative rates will be inversely proportional, so when one becomes more accurate, the other rate is sacrificed.

$$FP = \frac{1 - 2 * FN}{4 * FN + 2}$$

Figure 3: Equation of Relationship between False Positive and False Negative Rates

Model Name	Database Size	FP	FN
DNN	**~10000 images**	**1%**	**3%**
DNN	~ 1000 images	3%	7%
DNN	~ 100 images	29%	41%
RNN	~ 10000 images	5%	2%
RNN	~ 1000 images	10%	6%
RNN	~ 100 images	21%	20%
CNN	**~10000 images**	**4%**	**1%**
CNN	~1000 images	9%	12%
CNN	~100 images	39%	41%

Figure 4: Neural Network Options for Database Size and Model Type

There are two data files that are used, Terrain and Algae, as seen in Appendix D. The Terrain algorithm is used to detect water sources as the algae algorithm is used to detect harmful algae blooms in a specific source of water. These two sets of code use two data sets as they are used for different purposes. The main code used for this source water monitoring system is the algae algorithm detects the blooms this team needs to remove.

Decision Matrices and Evaluations

As seen in Appendix A, decision matrices were used to evaluate among the different design iterations. Three main decision matrices were used, each focused on a specific or combination of the PERSEID layers of the project. The first design iteration decision matrix focused solely on the Performance aspect of the project, as such it prioritized the battery life, the image quality, and the weight of the drone at the expense of the speed. The second design iteration decision matrix focused on both the performance and socio-cultural aspects of the project, it prioritized the battery life and the max speed at the expense of the image quality and the weight of the drone. The final decision matrix that was utilized focused on all aspects of the project, including the performance, environmental impact, regulatory concerns, and the socio-cultural implications. This decision matrix focused on battery life, the weight, the max speed at the expense of the image quality.

From all the design matrices it was determined that the Autel Robotics EVO II design performed best in all aspects of the PERSIED layer of project, and therefore was to be chosen as the final design of the project.

Final Proposed Design

General Design of Monitoring System

The third and final design iteration became the best design option due to the balance of all of the PERSEID layers. Each layer has importance and the third design iteration values each of the stakeholders needs and constraints to produce an optimal design for all of the parties involved. The drone that was selected for the final design iteration was the Autel Robotics EVO II, as seen in Figure 8 of Appendix B, this drone is environmentally friendly as it is made of biodegradable materials and weighs 1174 g, which increases its stability in windy weather. Other features offered by this design include: 40-minute battery life, 48-megapixel image quality, active and passive noise filtering technology such as sound shrouds and anti-sound waves to minimize noise pollution, and automated flightpath chartering system to minimize the number of operational drones and avoid restricted areas [5]. All of these design features have a balance between performance and the external constraints, which creates an overall effective design.

The final design has been confirmed to be a successful design based on a series of metrics. The first metric was the drone flight time, which with a 40-minute battery life, exceeds the minimum flight time for an operational drone system. The second metric used to measure the system was the camera quality and stability. The final proposed design has a 48-megapixel camera and a heavier weight of 1174g, which leads to high quality images. The final metric used was amount of people affected, and by using a drone with noise filtering technology and an optimized flightpath, the system surpassed the objective metrics.

Strengths	Weaknesses
Battery Life: This drone uses the battery life efficiently and has a large battery lifetime **False Non-Detects:** Minimizes amount of false detects and best helps the environment **Minimized Drone Stations:** This system low amount of drone stations for the flight path **Environmentally Friendly Material:** This drone uses material that is not as harmful as materials used in the pervious drones **Image Quality:** High image quality	**Drone Speed:** The drone speed is average; however, it will take longer than the first iteration to run through its pathway **Flight Stability:** Drone is lightweight, which affects the flight stability negatively

Table 4: Final Proposed Design Strengths and Weaknesses

Final Proposed Flightpath

The final flightpath proposed in the drone monitoring system has fewer drone stations located around the shore of Lake St. Clair, with each drone covering a greater area. When looking at the flightpath diagram in Figure 11 of Appendix B, the drone will follow a winding path that covers the shore of the lake and then loop back to the drone station. The majority of the flight time will be spent over the water to decrease the socio-cultural impacts from the drone system, and when flying over land, the drone will aim to avoid privacy-sensitive locations. The flight system will follow a set flightpath but will also be equipped with the ability to make real time decisions to adjust to the environment. The decreased amount of drone stations also has benefits for the environment by reducing the footprint of the system as a whole, which reduces the soil sealing and infrastructure building waste.

Final Proposed Neural Network

The final proposed machine learning algorithm is a dual neural network setup, which uses two neural networks independent of each other to determine the presence of algae. The first neural network is a deep neural network it contains a database size of 10,000 images it boasts a false positive occurrence of 1% and a false negative occurrence of 3%. The second neural network is a convolutional neural network it also has a database size of 10,000 images and false positive and false negative occurrences of 4% and 1% respectively. Our networks are rigorously trained on 10,000 image databases containing images of different lakes, conditions, and algae presence. The graph below of the left indicates the training and validation accuracy and the graph on the right shows the training and validation loss. The blue line indicates the performance of the machine learning algorithm during training increasing the overall accuracy with greater number of images. The orange line represents the accuracy and loss of the system during testing.

The system uses a dual conditional verification system, based on the results from each neural network the system decides the correct plan of action. If both or either network returns a positive result the system will notify an algae specialist and they will be sent to examine the lake. If both networks return a negative result, then it can be safely assumed that the lake does not contain algae.

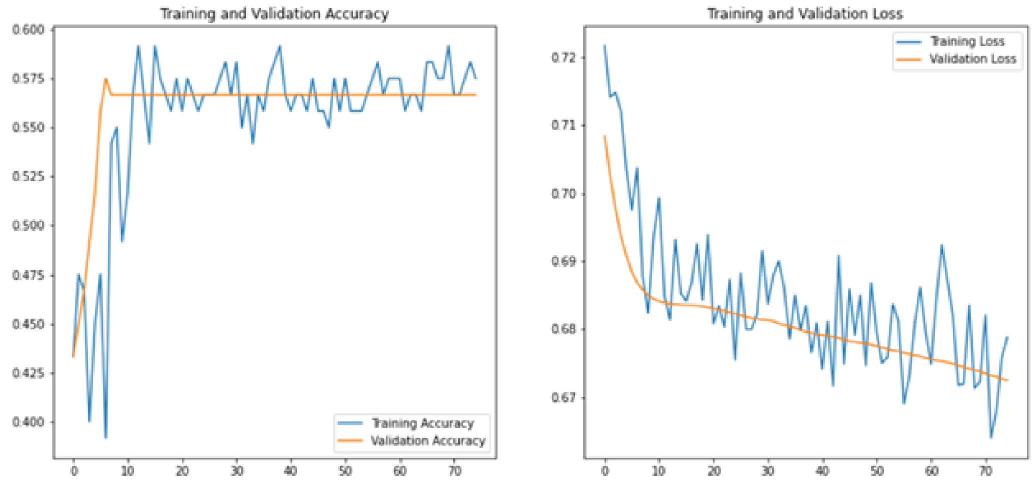

Figure 5: Neural Network Validation Accuracy and Loss

Adjustments of Design from PERSEID Layers

When analyzing the drone through the PERSEID layers, multiple changes have been made through each iteration which affects the previous layers before that specific design iteration. To begin, when looking at the final design, the drone's weight was heavily decreased due to environmental and socio-cultural concerns. The weight decrease reduced the environmental impact of the drone as less harmful material was used, and it reduced the noise pollution caused by the drone (the heavier the drone, the larger the noise pollution). This conflicted with the performance layer, as the drone's flight stability decreased slightly (the heavier the drone, the more stable); however, when looking at the drone, the design managed to balance out the importance of the performance, environmental, and socio-cultural layers.

Another conflict between the performance layer and other layers is the mass production of drones. To improve the performance of this system, more drone stations were used initially; however, the larger the drone stations, the larger the negative environmental and socio-cultural impact there will be. The regulatory layer also became a concern as the chances of injuries, property damages, and interference with the law increased. In order to mitigate this conflict, this team decreased the number of drones and drone stations used by implementing a larger battery life into the drone. This not only increased the drone's performance in another aspect; it also decreased the soil-sealing effect, noise pollution caused by the drones, and the likelihood of the regulatory aspect being concerning.

Working with Stakeholders Needs

When analyzing the needs of the stakeholders, the drone's physical system components and modifications were made accordingly. First, when looking at the water treatment plant, they requested the drone to provide early detections of algae blooms and the drone's performance to be high. This was considered through the drone's large battery life, camera quality, and speed. These three aspects of the drone allow it to be more effective and capture images of early blooming harmful algae. Moreover, another stakeholder need that was met was the environmental groups of Lake St. Clair. The drone machine learning algorithm ensures that the drone does not approach any environmentally sensitive areas and stays a certain amount of km away from them. This would reduce the chances of crashes in those areas and their effects on the wildlife. Another aspect of the drone that reduces crashes is the average speed of the drone. One change made to the drone was a decrease from a large speed to an average speed to reduce the chances of the drone malfunctioning or crashing.

To add on, the third stakeholder of this project was the government, as they needed the drone to avoid any interference with aviation laws. The machine-learning algorithm of the final drone would have specifications of how the drone flies in order to abide by these aviation laws found in Appendix C; for example, the drone should fly below 400 feet, it should stay 30m horizontally away from homes and more. In addition, this drone aligns with the fourth stakeholder's needs, the local residents, as we implemented noise cancellation technologies in order to reduce the noise pollution produced. The drone's physical components, such as the propellors, were adjusted accordingly (rounded propellors). The drone's flight path was also adjusted to allow the drone to fly more into the water rather than flying over the shore and disturbing the residents. Finally, the last stakeholder, the younger population, was concerned about degrading the water quality. This was considered by creating the final drone with bio-degradable material and polymer-based material to reduce the drone's negative impact on the water quality.

Conclusion

Algae blooms continue to be a problem today. The threat of algae blooms has become larger and larger over time. In order to mitigate this issue, a source water-monitoring system can be created for lakes in Ontario; specifically, Lake St. Clair, to help prevent algae blooms from becoming more and more prevalent in the world. This would allow safe drinking water to be more accessible to the communities around these source waters. When making the source-water monitoring system, multiple steps are considered through the PERSEID method. When looking forward into this project, there are many aspects of this project that may have been beneficial to modify or spend extra time on.

One step that may have been taken is further testing with the machine learning algorithm. This machine algorithm may differ heavily according to the epochs range and database size, so the more testing this team would have done with the code would have expanded the knowledge known for this algorithm. Moreover, the time spent researching the details of the drone technology and physical system components should have been greater to improve our drone alignments with the PERSEID layers. The details of cameras and data transfer may have also been another aspect of the source-water monitoring system that would be investigated if given more time, as that is an essential part of this objective.

When looking back at this project, this team learned that design process is crucial in an engineering process as its the base what engineering projects are built upon. The design process allows the team to compact multiple designs with constraints into one final effective solution. This team also learned a lot of team dynamics as this team worked together through schedule conflicts caused by different disciplines. In terms of team dynamics, this team also benefited from different disciplines analyzing and solving problems in various ways.

In addition to the design process, a beneficial aspect of the design process would be testing drones around Lake St. Clair for more insight on how to adjust the drone accordingly. In terms of team dynamics, next time, this team would look to set up more team meetings outside of studio time to improve the quality of the work. Overall, this project has offered this team a beneficial experience to help communities around source waters which expanded our knowledge of the process of an engineering-based project.

References

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Appendix A – Drone Decision Matrix

Drone Specifications

Drone Options [5]	**Battery Life**	**Weight**	**Max Speed**	**Image Quality**
DJI Mavic Air 2S	25 minutes	4250 g	94 kph	20 Megapixel
EACHINE Wizard X220	15 minutes	535 g	115 kph	16 Megapixel
Autel Robotics EVO II	40 minutes	1174 g	72 kph	48 Megapixel
PowerVision PowerEgg X Wizard/Basic	30 minutes	860 g	65 kph	12 Megapixel
DJI Mini 2	31 minutes	259 g	57 kph	12 Megapixel

First Design Iteration – Performance Only

Drone Options	**Battery Life (5)**	**Weight (4)**	**Max Speed (3)**	**Image Quality (5)**	**Total**
DJI Mavic Air 2S	3 15	5 20	5 15	4 20	70
EACHINE Wizard X220	5 25	3 12	5 15	3 15	67
Autel Robotics EVO II	5 25	3 12	4 12	5 15	64
PowerVision PowerEgg X Wizard/Basic	4 20	2 8	2 6	2 10	44
DJI Mini 2	4 20	1 4	1 3	2 10	37

Second Design Iteration – Performance & Socio-Cultural

Drone Options	Battery Life (5)	Weight (2)	Max Speed (5)	Image Quality (3)	Total
DJI Mavic Air 2S	3 15	1 2	5 25	4 12	54
EACHINE Wizard X220	5 25	3 6	5 25	3 9	65
Autel Robotics EVO II	5 25	2 4	4 20	5 15	64
PowerVision PowerEgg X Wizard/Basic	4 20	4 8	2 10	2 6	44
DJI Mini 2	4 20	5 10	1 5	2 6	41

How Socio-cultural concerns relate to drone attributes:

1. Drone speed and flight duration (battery life) contribute to noise pollution. Noise pollution ranks as the most important socio-cultural concern for the drone monitoring system.

2. The image quality contributes to the privacy of the stakeholders. Privacy ranks second in terms of socio-cultural concerns.

3. Drone speed and weight contribute to the drone's ability to cause injuries and property damages. Injuries and property damages rank the lowest in terms of socio-cultural concerns because the drone will be actively avoiding populated areas and buildings or structures.

Third Design Iteration – All PERSEID Layers

Drone Options	Battery Life (5)	Weight (3)	Max Speed (3)	Image Quality (2)	Total
DJI Mavic Air 2S	3 15	1 3	4 12	4 8	38
EACHINE Wizard X220	5 25	2 9	2 6	3 6	43
Autel Robotics EVO II	5 25	5 15	5 15	5 10	65
PowerVision PowerEgg X Wizard/Basic	4 20	4 12	4 12	2 4	48
DJI Mini 2	4 20	2 6	3 9	2 4	39

How environmental and regulatory concerns relate to drone attributes:

1. Main environmental concerns: Noise pollution, Environmental pollution.
2. Noise pollution is closely related to drone speed and duration.
3. Environmental pollution will be more dependent on the battery life attributes of the drone. Larger battery life means less wastage, which may lead to environmental contaminations.
4. Main regulatory concerns: Operating 5.6km from airports, operating 30 m away from any buildings or bystanders (injuries and property damages).
5. In terms of regulatory concerns drone weight and speed will rank as the highest concerns as they lead to increased potential for injuries and property damages.

DJI Mavic Air 2S:

Figure 6: DJI Mavic Air 2S Drone.

EACHINE Wizard X220:

Figure 7: EACHINE Wizard X220 Drone.

Autel Robotics EVO II:

Figure 8: Autel Robotics Evo II Drone.

Appendix B – Drone Flight Path

1st Design Iteration:

Figure 9: First Design Iteration Flight Path.

Legend:

- Orange Dots: Drone Stations
- Orange Lines: Flight path for Drone at specific drone station
- Black Line: Divides border between U.S. and Canadian Side
- Red Box: Non-Flight area

2nd Design Iteration:

Figure 10: Second Design Iteration Flight Path.

Legend:

- Orange Dots: Drone Stations
- Orange Lines: Flight path for Drone at specific drone station
- Black Line: Divides border between U.S. and Canadian Side
- Red Box: Non-Flight area

3rd Design Iteration:

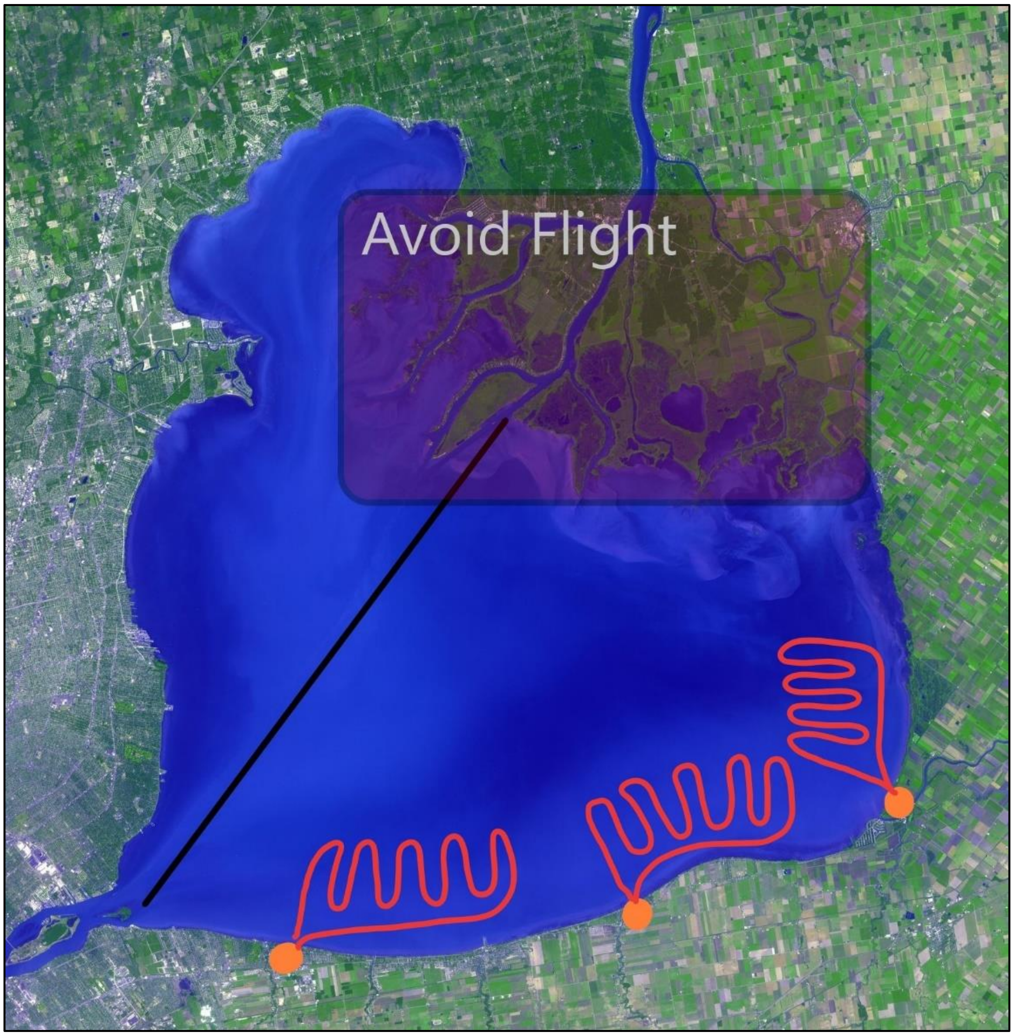


Figure 11: Third Design Iteration Flight Path.

Legend:

- Orange Dots: Drone Stations
- Orange Lines: Flight path for Drone at specific drone station
- Black Line: Divides border between U.S. and Canadian Side
- Red Box: Non-Flight area

Appendix C – Overview of Design Constraints (Data)

Broad aspect	**Specific aspect**	**Designing Ideas**	**Short Description of Designing Ideas**
Performance Consideration	Algae Detection	High-Performance Algorithm	Convolutional Neural Networks
			Deep Neural Networks
			Hybrid of Both
Socio-Cultural Consideration	Local Acceptance	Privacy Concern	The residents living around the water we plan on working on have stated that they don't want the noise of the drones disturbing them during their daily activities. The consequence of us disturbing the public can be the possible shutdown of our mission.
		Collected Data Security	In many situations, people will be concerned about their data being leaked; however, the only situations it can be acceptable in is if the government needs it. We want our drone's data to be as secure as possible as the images captured may include something that we cannot share.
		Wellbeing of Residents	According to human ethics, drones should be used to legal and moral reasons only. If we cause a significantly large amount of noise pollution, that can violate the morals we want to follow.
Regulatory Consideration	Restrict Area Avoidance	Distance Requirement	5.6 km from airports [3].
			Must operate at a max altitude of 122m [3].
			Drone must operate 30m away from any buildings, structures, and bystanders [3].

Environmental Consideration	Pollution Minimization	Noise Pollution	One of the stakeholders states that the noise will be a concern to the neighbourhoods around the source water; thus, we need to keep that as a priority during this objective.
		Wildlife Impacts	Research states that there has been an increase of vehicle-wildlife throughout the recent years, so this team needs to reduce the chances of that happening [4].
		Least Harmful Pollution	The materials used in components such as the blades or the battery can impact the environment greatly, so the goal would be to reduce that impact as much as possible.

Appendix D – Neural Network Algorithm Code and Output

Algae Code

```
[ ]  from zipfile import ZipFile
     file_name = 'Week7.zip'

     with ZipFile(file_name, 'r') as zip:
       zip.extractall()
       print('Done')
```

```
Done
```

```
import matplotlib.pyplot as plt
import seaborn as sns

import keras
from keras.models import Sequential
from keras.layers import Dense, Conv2D , MaxPool2D , Flatten , Dropout
from keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import Adam

from sklearn.metrics import classification_report,confusion_matrix

import tensorflow as tf

import cv2
import os
import numpy as np

labels = ['alge', 'noalge']
img_size = 224
def get_data(data_dir):
    data = []
    for label in labels:
        path = os.path.join(data_dir, label)
        class_num = labels.index(label)
        for img in os.listdir(path):
```

```
                try:
                    img_arr = cv2.imread(os.path.join(path, img))[...,::-1] #conver
                    resized_arr = cv2.resize(img_arr, (img_size, img_size)) # Resha
                    data.append([resized_arr, class_num])
                except Exception as e:
                    print(e)
            x = np.array(
               data,
               dtype=object,
            )
        return x

train = get_data('./Week7/new/train')
val = get_data('./Week7/new/test')


x_train = []
y_train = []
x_val = []
y_val = []

for feature, label in train:
  x_train.append(feature)
  y_train.append(label)

for feature, label in val:
  x_val.append(feature)
  y_val.append(label)
```

```
# Normalize the data
x_train = np.array(x_train) / 255
x_val = np.array(x_val) / 255

x_train.reshape(-1, img_size, img_size, 1)
y_train = np.array(y_train)

x_val.reshape(-1, img_size, img_size, 1)
y_val = np.array(y_val)


datagen = ImageDataGenerator(
        featurewise_center=False,  # set input mean to 0 over the dataset
        samplewise_center=False,  # set each sample mean to 0
        featurewise_std_normalization=False,  # divide inputs by std of the data
        samplewise_std_normalization=False,  # divide each input by its std
        zca_whitening=False,  # apply ZCA whitening
        rotation_range = 30,  # randomly rotate images in the range (degrees, 0
        zoom_range = 0.2, # Randomly zoom image
        width_shift_range=0.1,  # randomly shift images horizontally (fraction o
        height_shift_range=0.1,  # randomly shift images vertically (fraction of
        horizontal_flip = True,  # randomly flip images
        vertical_flip=False)  # randomly flip images


datagen.fit(x_train)

model = Sequential()
model.add(Conv2D(32,3,padding="same", activation="relu", input_shape=(224,224,3)
model.add(MaxPool2D())
```

```
opt = Adam(lr=0.000001)
model.compile(optimizer = opt , loss = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True))

history = model.fit(x_train,y_train,epochs = 75 , validation_data = (x_val, y_val))

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

epochs_range = range(75)

plt.figure(figsize=(15, 15))
plt.subplot(2, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(2, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')
plt.show()
```

Terrain Code

```
from zipfile import ZipFile
file_name = 'data.zip'

with ZipFile(file_name, 'r') as zip:
  zip.extractall()
  print('Done')
```

```
Done
```

```
[ ] %tensorflow_version 2.x
import tensorflow as tf
device_name = tf.test.gpu_device_name()
if device_name != '/device:GPU:0':
  raise SystemError('GPU device not found')
print('Found GPU at: {}'.format(device_name))
```

```
Found GPU at: /device:GPU:0
```

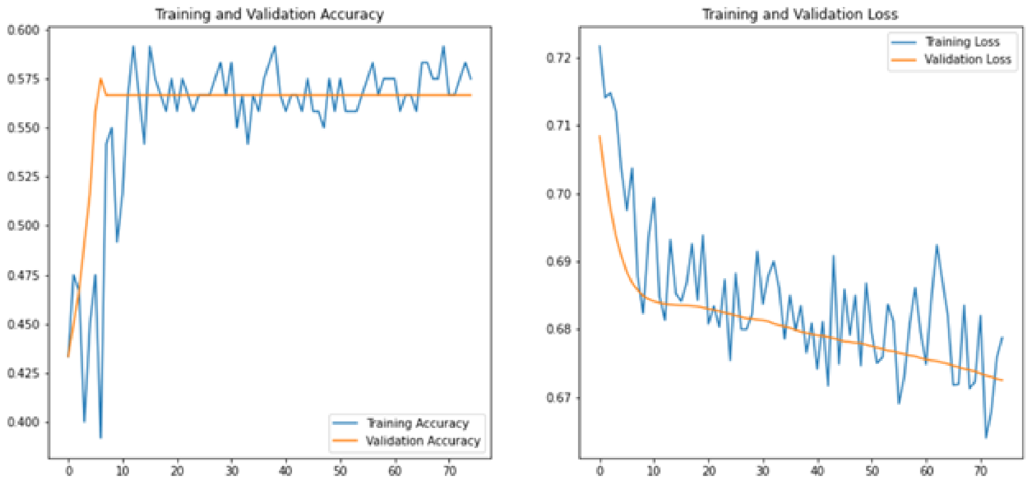
```
[ ] import matplotlib.pyplot as plt
import seaborn as sns

import keras
from keras.models import Sequential
from keras.layers import Dense, Conv2D , MaxPool2D , Flatten , Dropout
from keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.optimizers import Adam

from sklearn.metrics import classification_report,confusion_matrix

import tensorflow as tf

import cv2
import os
import numpy as np

labels = ['desert', 'water']
img_size = 224
```

```
def get_data(data_dir):
    data = []
    for label in labels:
        path = os.path.join(data_dir, label)
        class_num = labels.index(label)
        for img in os.listdir(path):
            try:
                img_arr = cv2.imread(os.path.join(path, img))[...,::-1] #convert BGR to RGB format
                resized_arr = cv2.resize(img_arr, (img_size, img_size)) # Reshaping images to preferred size
                data.append([resized_arr, class_num])
            except Exception as e:
                print(e)
        x = np.array(
           data,
           dtype=object,
        )
    return x

train = get_data('./data/train')
val = get_data('./data/test')


x_train = []
y_train = []
x_val = []
y_val = []

for feature, label in train:
  x_train.append(feature)
  y_train.append(label)

for feature, label in val:
  x_val.append(feature)
  y_val.append(label)

# Normalize the data
x_train = np.array(x_train) / 255
x_val = np.array(x_val) / 255
```

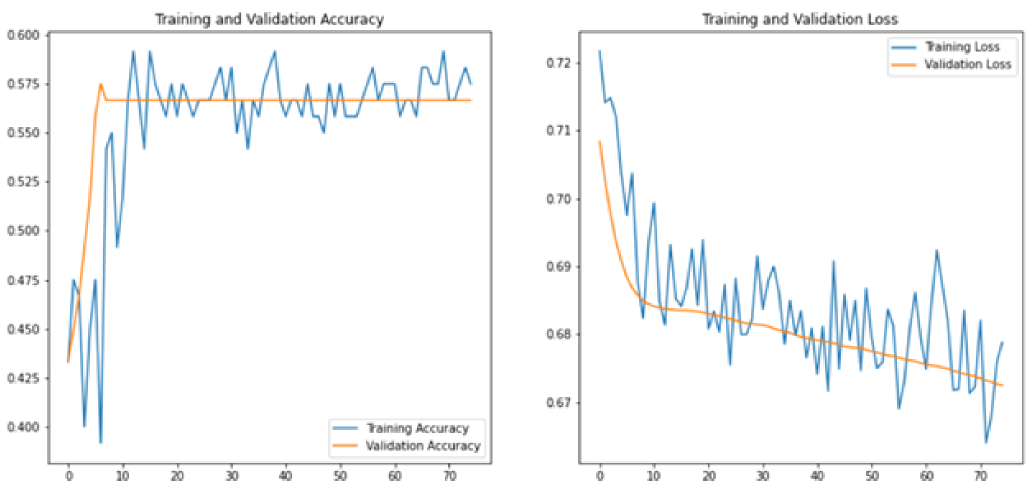
```
x_train.reshape(-1, img_size, img_size, 1)
y_train = np.array(y_train)

x_val.reshape(-1, img_size, img_size, 1)
y_val = np.array(y_val)


datagen = ImageDataGenerator(
        featurewise_center=False,  # set input mean to 0 over the dataset
        samplewise_center=False,  # set each sample mean to 0
        featurewise_std_normalization=False,  # divide inputs by std of the dataset
        samplewise_std_normalization=False,  # divide each input by its std
        zca_whitening=False,  # apply ZCA whitening
        rotation_range = 30,  # randomly rotate images in the range (degrees, 0 to 180)
        zoom_range = 0.2, # Randomly zoom image
        width_shift_range=0.1,  # randomly shift images horizontally (fraction of total width)
        height_shift_range=0.1,  # randomly shift images vertically (fraction of total height)
        horizontal_flip = True,  # randomly flip images
        vertical_flip=False)  # randomly flip images


datagen.fit(x_train)

model = Sequential()
model.add(Conv2D(32,3,padding="same", activation="relu", input_shape=(224,224,3)))
model.add(MaxPool2D())

model.add(Conv2D(32, 3, padding="same", activation="relu"))
model.add(MaxPool2D())

model.add(Conv2D(64, 3, padding="same", activation="relu"))
model.add(MaxPool2D())
model.add(Dropout(0.4))

model.add(Flatten())
model.add(Dense(128,activation="relu"))
model.add(Dense(2, activation="softmax"))

model.summary()
```

```
model.summary()


opt = Adam(lr=0.000001)
model.compile(optimizer = opt , loss = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True) , metrics = ['accuracy'])

history = model.fit(x_train,y_train,epochs = 75 , validation_data = (x_val, y_val))

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']
loss = history.history['loss']
val_loss = history.history['val_loss']

epochs_range = range(75)

plt.figure(figsize=(15, 15))
plt.subplot(2, 2, 1)
plt.plot(epochs_range, acc, label='Training Accuracy')
plt.plot(epochs_range, val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.title('Training and Validation Accuracy')

plt.subplot(2, 2, 2)
plt.plot(epochs_range, loss, label='Training Loss')
plt.plot(epochs_range, val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.title('Training and Validation Loss')
plt.show()
```

Model Output



Smaller Data Base Size



Larger Data Base Size

Appendix E – Synchronous Group Worksheets

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Week 2: Synchronous Design Studio

Team Building and Lessons Learned

Stage 1: Team Charter

As you are getting started to work on your project, one of the very first steps is to create a team charter. A team charter is a document that outlines the purpose of your team (i.e. your end goal), as well as detailed information about the team members.

Please list all the team members' information below.

Member	Full name	Preferred name	Email
Team Member 1	Earl Ryan Parker	Ryan	Parkee7@mcmaster.ca
Team Member 2	Nathan Marttunen	Nathan	marttunn@mcmaster.ca
Team Member 3	Cheng Su	Cheng	Suc27@mcmaster.ca
Team Member 4	Harikashan Thayeswaran	Hari	thayeswh@mcmaster.ca
Team Member 5	Ronnie Mushegera4	Ronnie	musheger@mcmaster.ca

Take a picture of your team. Be creative! Paste your team portrait below.

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In a few sentences, please describe your team's goal for ENGINEER 2PX3 and what you are aiming to achieve.

- Our teams goals for engineer 2px3 is to:
- To learn how to manage big and complex projects efficiently.
- we want to be more experienced in completing engineering projects while using the Engineering 2PX3 design process
- Creating high quality solutions that meet social, economic, health, and functional objectives and constrains.
- Creating a equal and diverse work experience among the group and teams
- Develop our technical skills (CAD, Programming. etc.) that will be applicable in our future careers

2

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Please outline 3 strengths for **team member 1** with one example or specific experience for each.

Strength	Example
Self-Discipline	During the summer I set a goal to learn iOS and web development. In order to do so I had to stay self-disciplined and hold my self-accountable.
Cooperation	During 1P13A I worked with many engineering teams where I exhibited my strength in corporation to made sure to listen to everyone and cooperate when necessary
Achievement-Striving	During the first term of the school year, I tried very hard to strive to achieve excellence in my courses.

Please outline one area of improvement for **team member 1**.

An area of improvement for Earl would be orderliness, more specifically becoming well organized

3

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Please outline 3 strengths for **team member 2** with one example or specific experience for each.

Strength	Example
Goal Oriented / Determined	I want to complete assignments and tasks with as much effort as possible and I work better when there is a clear goal or target to reach
Agreeableness / Cooperation	When working with team members in 1P13, I would work well with others, and allow everyone to participate and share ideas
Natural Reactions / Patience	I tend to remain calm in stressful situations and work well under pressure.

Please outline one area of improvement for **team member 2**.

An area of improvement can be my extraversion and being more comfortable in group and social situations. Being able to freely talk and share ideas without being shy.

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Please outline 3 strengths for **team member 3** with one example or specific experience for each.

Strength	Example
Extraversion	Tend to build a friendly connection in work and life.
Organization	Usually organize the workload in multiple ways.
Patience	tend to remain calm when facing difficulties.

Please outline one area of improvement for **team member 3**.

- Working on improvement of machine learning within the water monitoring group project.

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Please outline 3 strengths for **team member 4** with one example or specific experience for each.

Strength	Example
Agreeableness	- During a project to build a medical container during a 1p13 project, my teammate and I had different ideas with what we wanted to create. I decided to proceed with his idea with a few changes because I recognized that his idea was more efficient than mine and it would benefit the group.
Natural reactions	- I often get worried about submissions during our 1p13 design studios. In one situation during project 1, I got worried and doubled checked a solution on a milestone we submitted, and I noticed a mistake. I brought this to the attention of my group, and we fixed the mistake in time; thus benefiting us.
Conscientiousness	- During my 1p13 projects, I consistently made sure that our files were organized and that saved us an enormous amount of time when working on our project.

Please outline one area of improvement for **team member 4**.

- I need to improve on being open to different experiences and try new things. This would benefit our team greatly. I also need to be more extroverted and be open to my teammates.

6

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Please outline 3 strengths for **team member 5** with one example or specific experience for each.

Strength	Example
Conscientiousness.	I like to keep my work organized and complete tasks in a timely manner.
Agreeableness.	I am able to cooperate and work well in groups.
Openness To Experiences.	I have a high interest in theoretical physics and emerging technologies.

Please outline one area of improvement for **team member 5**.

- An area of improvement could be making more efficient use of advanced time management and stress techniques and tools.

Lastly, please outline the order of student presentations of your team.

Week	Member(s)
Weeks 3 and 7 *	Nathan
Weeks 4 and 8	Ronnie
Weeks 5 and 9	Harikashan
Weeks 6 and 10	Cheng and Earl
Which Group are you paired with? Self-Driving-38 and Water-22	

*For teams of 5, 2 members can present on their chosen weeks other than weeks 3 and 7

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Stage 2: EDI

Have you ever been on a team and felt like you weren't being heard? Alternatively, maybe your role in teams has usually been one of directing the group's work. If you have been in either situation, it may be time for a change. Go through the activities on Avenue to Learn under [4-Design Studios → Week 2 → EDI]

-Now that you have examined this set of scenarios, you are invited to complete an individual task. In a personal journal, write out **three things** that you commit to do so that you can increase a sense of inclusion in this class or in any situation you might encounter as an undergraduate student. Refer back to this journal entry later, as you complete reflections in this course.

Personal Journal

1. A group communication technique that could be employed to increase inclusivity in the group is allowing group members to speak in-turns uninterrupted.
2. During the group conversation, we found that there are some red lines when having communicating within teams. We think that the principle to make a friendly communicating is to stand the others' side. For example, when trying to speak up for somebody, ask them first to make sure that you are not taking away their right to speak. And when facing something like back-handed compliment, problems like this can be easily avoid.
3. The third thing is also the new aspect of building a equal working environment for us. Toxic working environment isn't always means being not respectful and being mean to others. We found that toxic team working can have the form of "one people taking up all the work/speech". Scenario like these will not help everyone in the team to develop themselves. After learning these and working on five scenarios, we as group will try to put effort in to build a more inclusive team work environment.

9

Stage 3: Project Activity #1

Each of the 4 projects in this course were chosen because they highlight the interdisciplinary concepts between the different fields. With this in mind, each engineer interprets a problem and creates objective and constraints based on their experience and background. In this activity, you will be learning about your team members' disciplines and how it impacts your project.

Please state your project, the disciplines it focuses on and the specific aspects of each discipline (e.g., Electrical Engineering - Electromagnetics, Mechanical Engineering – CAD, etc.)

Project: Water Monitoring			
	Field 1	Field 2	Field 3 (Optional)
Discipline	Electrical Engineering	Software Engineering	Mechatronics Engineering
Aspect	Circuit Design	Programming / Machine Learning	Micro-controllers

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2

Consolidate the technical performance constraints each member came up with in the asynchronous activity

Field 1	Field 2	Field 3 (Optional)
Drone Battery life	Image processing	Size of drone/ Material selection
Drone Altitude	Error Analysis	Number of gears for drone
Drone Control	Path Optimization	Cad model
Drone Durability	Image storing	Cost

As a team, discuss the technical constraints and decide on one important constraint per field. Make sure you justify your reasoning.

Field 1	Field 2	Field 3 (Optional)
Drone Control	Image Processing	Cost

Justification:

- Drone Control is an important technical constraint to consider because the ability to navigate the drone is the center to all other constraints. We need to be able to control the drone in a well manner in order prevent any damage happening to the drone.
- Image Processing is extremely important as if you cannot identify the surroundings of the drone (especially the algae), the main objective would not be met
- The cost of the water-source drone monitoring system has to be less than traditional water monitoring methods for it to be an acceptable investment for the stakeholders.

The rest of the PERSEID layers include Environmental, Regulatory, and Socio-cultural constraints. As a team, brainstorm on the constraints that correspond to these layers and are relevant to your project. Make sure you justify your reasoning.

Layer	Constraint
Environmental	Noise pollution, battery pollution, turn over rate
Regulatory	Drone Altitude, Machine Learning Algorithms
Socio-cultural	Privacy concerns

Justification:

Pollution: Reducing pollution from batteries helps environment. Reducing noise pollution helps surrounding neighbourhoods / people

Lifespan / Turn-over rate: Making the drone with enough quality to not need repairs or replacements too often

Drone Altitude: Regulated to keep airspace free for airplanes and helicopters

Machine Learning Algorithms: Make sure programs have enough security and safety measures to operate safely

Privacy Concerns: Socio-cultural, people don't want their privacy be intruded by a flying drone

Submission Instructions

1. Upload a *.**PDF** copy of the Wk-2 - Synchronous Design Studio 2 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 2** by Jan 23rd
    - Use the following naming convention: **Tut#_Team#_SynchDS2.pdf**

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2

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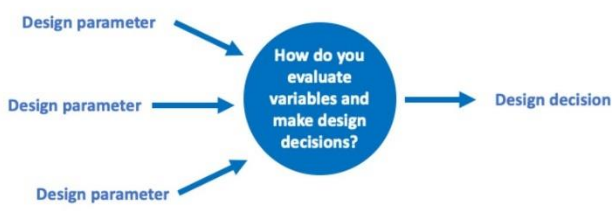
Week 3: Synchronous Design Studio

Source Water Quality Monitoring Project
System Definition

OVERVIEW

This activity helps you identify the most important elements of the complex challenge. Engineers call this process System Definition or defining the Design Scope. In either case, it is about choosing the things you want to consider for your design and putting aside others that you simply do not have time for and may not influence the outcome of your design as much as other factors. For example, in considering the design of a source water monitoring system you will likely not consider the impact of extreme weather events on image quality – you are likely to land drones during these times to avoid damage.

In general, even the most complex design process will attempt to break down all possible considerations into a smaller, more manageable set of design variables and ways to compare the merits of each consideration.



In this activity, you are asked to decide on the key variables that you will be considering to help you make design decisions.

Once you have identified the principal design factors or parameters and have a sense of how you will assess the merits of each as compared to others, you have effectively defined your "System" – i.e., a reduced and more practical representation of the real application that you can more effectively work with to make design decisions.

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KEY ASSUMPTIONS PROVIDED

To identify key parameters, you will need some basic assumptions to reduce the total number of possible choices.

System Components

Consider the many necessary components of an aerial monitoring system. You will not have time to specify/design every single component. What components will you focus on (knowing that you must use machine learning and image analysis to conduct a false positive/negative analysis)?

Brainstorm all possible system components and discuss key considerations as a group. As appropriate, research and review resources.

Step 1 (20 minutes): Brainstorm all possible physical system components. What are some of the challenging decisions that you can foresee? What kind of potentially conflicting design choices can you see ahead of you?

1. **Drone**

-Drone Propeller: Factors that can contribute to the noise of the propeller such as the length of the propeller, rounding off the tips of the propeller and the overall design of the propeller. We would also need to decide between active or passive noise cancellation for the benefit of the residents around the lakes.

-Drone Battery: A decision to be made is battery duration how long will the drone be able to fly. This will be considered when determining flightpath around environmentally sensitive areas. We would also have to consider what type of battery we need (ex. Rechargeable or Non-Rechargeable).

-Drone Motors: A decision to be made for the motor would be what size/weight we would make it to account for power efficiency and noise at the same time.

-Drone Controller: A conflict decision to be make is the production cost (whether physical controller or controlled by phone application)

- Drone Size/Weight: There would be a conflicting decision when prioritizing the weight for better navigation through wind or the battery life of the drone.

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2. **Camera**

-Camera Lens: A conflicting decision we must look into is the resolution/power of the camera lens due to the fact that we would need a camera lens that would support the operational altitude imposed by the constraints of the stakeholders.

-Camera Support: A difficult decision to be make is select a support for camera that can stand the constant move and stop of the drone, and also the possible shaking caused by the drone propeller.

- Camera Size/Weight: Typically, a camera of a larger size/weight has better functionality with image processing. A conflicting decision we have to make is to either prioritize the size/weight of the drone for better functionality or the battery life of the camera.

3. **Infrastructure Areas**

- Charging Stations: A difficult decision we need to make is where the charging station will be located in order to avoid environmentally sensitive or government restricted areas. We also need to consider the tradeoffs between the optimal number of stations required successfully implement the drone monitoring system vs the environmental impact of these stations.

- Landing Sites: A difficult decision we need to make is where the landing sites will be located in order to be avoid environmentally sensitive or government restricted areas. We do not want to disturb the residents which is a big factor according to stake holders.

4. **Drone Flight Controller**

-GPS Module: Usually, the more expensive a GPS component is, the better it can navigate. There would be a conflicting decision between prioritizing the cost of the module or the functionality of the module.

Step 2 (20 minutes): What will the operating specifications and guidelines of your system be? These may be associated with the geographic area, extent, and conditions, as well as the combination of accuracy requirements and physical system elements. List all the operating specifications that you can think of.

1. **Flight Path**

- Abiding by the government set aviation laws. We need to avoid high population areas: due to stakeholders' comments imposing a less disturbing drone flight
- When deciding what pathway we take, we need to align the path with the closest charging stations for a specific drone

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2. **Flight Duration**

- When deciding flight paths from one operational location to another, we will need to optimize for the shortest flight path while minimizing the violation of privacy laws, and environmental concerns.
- When deciding what pathway we take, we need to consider the battery life and what effects the battery life.

3. **Operation Location**

-Should be a safe location without too many people to avoid possible collisions and disturbances.
- We need to be mindful of where we would place the charging stations as we would need to avoid environmentally sensitive areas and restricted areas.

IDENTIFYING DESIGN PARAMETERS

Principal screening considerations

Additionally, you are provided with a reduced starting set of factors to consider for the design relative to the PERSEID screening process. They are as follows:

Performance

1. Rate of false detects and false non-detects. Have these been minimized through the specified physical system components and operating conditions.
2. What are the data collection requirements?

Socio-cultural

1. Privacy
2. Noise
3. Unintended consequences

Policy/Regulatory

1. Canadian Aviation Regulations
2. Trespass Act
3. Offences against Air or Maritime Safety

Environmental

1. Impact of crashes on ecosystems
2. Noise pollution
3. Battery life

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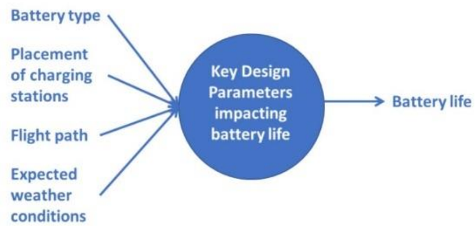
For each of these, you will need to discuss and decide on which factors will influence a particular design decision the most. For example, the following diagram illustrates a hypothetical set of design parameters that could influence the flight path.



So, the design team would have to decide which factors affecting the value of the parameter would optimize battery life and flight path while minimizing the number of charging stations required. In a real project, there would be more factors influencing the battery life, but we must be careful to keep the scope of this project manageable within the timeframe of this course.

For this Design Studio activity, you will consider in more detail, the design parameters that you believe are more important or influential to the function of your design. AS A FIRST STEP IN THIS ACTIVITY, FOCUS ONLY ON THE TECHNICAL PERFORMANCE CONSIDERATION.

Step 3 (50 minutes): Design parameter decisions

Based on the discussion in Steps 1 and 2 above,

1. What are the parameters that the team believes would be most important in helping you make design decisions for the above considerations?
2. For each of the parameters, what are some of the key considerations that you can inform with these parameter inputs? It is entirely acceptable and even preferable for a single parameter to help you with multiple considerations.
3. How will you measure, quantify, or assess the parameter? Is it measurably objective or more subjective?

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4. Are there any important assumptions that you will make when applying a particular parameter? e.g., for weather-related parameters, you could assume that you will ground your drone whenever the wind exceeds a certain threshold, but that this assumption will leave you with enough fly time to obtain whatever your required number of images is.

Please use the following table. At this stage, it is normal to begin with a larger set of parameters that focus on technical performance screening but try not to exceed 5 as an initial number. The list should attempt to address as many of the design concerns as possible be useful for assessing options for both physical system and operating conditions. Note that we expect the table might look "ugly" afterwards, filled with line breaks, extra spaces etc. Remember, this is your opportunity to brainstorm!

Parameter choice	Which consideration is impacted?	How will you measure, calculate, or assess the impact of the parameter?	Any important assumptions?
1. False detect and false non-detects through specified physical system components and operating conditions	Camera Machine Learning System	- Error analysis using performance metrics by performing two machines learning classification exercises. - Deciding if a particular image from a different database contains an image of a lake with or without algae. We can determine the rate of false and non-detects by comparing and performing error analysis on the predictions of the monitoring system's AI in contrast to a pre-existing database of water-body pictures and their associated algae bloom test results (conducted through conventional testing methods).	- Accounting for error because some error is always going to happen
2. Battery Life	Motor, Weight/Size Flight Path and duration	- Range in terms of distance: ex. How far can the drone travel for a full battery life - Time: ex. how long it will take to get from one point to another	- Average drone flight time of 20 min

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3. Privacy Concerns	Camera Flight Path	- Surveys: We can ask the residents around the lake to talk about their privacy concerns and generate a rating for how good someone's privacy is	- Automated surveys will be sent to all the near-by residents. Survey results will be converted into a ratings of the performance on the minimization of privacy concerns.
4. Canadian Aviation Regulations	Drone as a whole Flight Path	- Average number of infractions per trip - Know the laws, and no not violate any of them	- Fines are expensive. \$15,000 for a commercial drone to put people at risk
5. Unintended/Unexpected Consequences	Machine Learning Algorithm Weather	- Average number of unexpected occurrences per trip	- We will need to have an automated or public input-based way of identifying and determining unexpected drone behaviour/occurrences.

Step 4: Global Assumptions (20 min)

List any major assumptions that you made when identifying the five parameters. Describe how they are helpful to explain, support, and affect your parameter choices to some extent. Examples would include: (1) You will be able to specify a battery to meet the needs of your technical specifications, and so batter life is outside the scope of your design; (2) Algal blooms will not occur during very cold or freezing periods, and flights only need to occur during relatively temperate periods.

Choosing an operation location is required to make choices later down the road and many other choices will fall into place once a location is chosen.

- Lake St. Clair – Near Windsor, ON. Algae blooms often, most recently August 2021
  Lake is between Lake Huron and Lake Erie, so the water quality from St. Clair affects other lakes downstream (mainly Lake Erie)

Lake St Clair shore length: 210+204=414km (Terry Gibb, 2022)

- The reason why we choose Lake St Clair to monitor the water quality is that it serves as water sources for nearly five million population for people in United State and Canada (Terry Gibb, 2022)
- Though not in the list of the great lakes, it has its vital position. However, lake with such importance doesn't have a considerable water quality for human-use. (EPA)

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Avg drone speed: 80km/h (Khan, 2021)
- DJI Inspire 2
- this drone can go from 0 to 80 km/h in under 4 seconds and has a max speed of 108 km/h. (DJI)

Avg drone battery life: 1/3h
- DJI mini2: Max 31min battery life (DJI)

Drone coverage when have battery: 80/3=26.666667km
How many drones take to check around: 414/27=15.333333 drones/battery lives
How long it takes 15 drones/battery-lives to check around: 414/80=5.175 hours

IEEE Format Work Cited

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Final note

This activity is a first step. In addition to the above starter consideration (i.e., two screening criteria per layer), you can also add considerations and parameters of your own as you progress through the design iteration stages of PERSEID to help you assess options. More details will follow in later weeks.

Submission Instructions

1. Upload a *.**PDF** copy of the Wk-3 - Synchronous Design Studio 3 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 3** by Jan 30th
    - Use the following naming convention: **Tut#_Team#_SynchDS3.pdf**

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Week 4: Synchronous Design Studio

Source Water Quality Monitoring
System Definition Continued

Overview and Goals

This activity is a continuation of last week's activity on system definition, in which you took your first pass in discussing the various considerations and choices. This week, you will:

- Identify formal metrics of the system. Explore how an underlying metric such as false detects and false non-detects can be used in several ways.
- Consider parameters/input and outputs to the system.
- Think about what quality attributes are important for source water quality monitoring systems.
- Formally describe your system.

By this point, you should have an idea about the physical components you will need for your system, as well as the types of operating protocols / guidelines you need to specify. You will need to choose a geographic area to obtain necessary data (e.g., for Hamilton, you can access weather information, map ecologically sensitive areas Cootes Paradise Marsh in Hamilton, etc.). If you have not done so, please take a few minutes either before the Design Studio or at the beginning to confirm your group's choice of geographic area. Google Earth may be a helpful tool in choosing your geographical area.

Ethics and unintended consequences (15 minutes)

In your team, discuss the asynchronous activity you completed this week. Have each group member share an unintended consequence that they identified. Consider two or three unintended consequences and consider how these might be mitigated. Document this discussion below.

- When building the drone, we have to take into account unintended consequences such as crashes, system malfunctions, swerving off a pathway, and impacts of weather. We would need to receive or find a way to bring the drones back to a station (control station) without damaging the environment or disturbing the residents around the area. The stakeholders are very stern upon privacy, and we have to take privacy as a top priority during this objective. We can do this by implementing a separate emergency return algorithm into the drone or a team of people to receive drones that have went off track.

- The operation location, along with the required infrastructure will determine how far the drone needs to fly in-land to recharge / upload data. Also, determining who / what is put at risk, such as flying over protected wetlands or private property. Choosing a balanced flightpath and landing location that does not do any harm while being efficient will be challenging. Future infrastructure (houses stores, etc.) being built around the landing locations can lead to putting people too close to the drone.

- We must consider the unintended consequence of the drone being hacked. An individual can intercept the drone, take control, steal data, or repurpose it. In order to mitigate for this consequence, we can increase the efficiency of our security within our algorithm. We can also have a back-up system that shuts down the drones if needed.

Revisit constraints and parameters (60 minutes)

Last week, you began considering the constraints and parameters. Now that you have had more time to think about your source water quality monitoring system, revisit those discussions and see if your thoughts have changed or you now have more information, input, or a clarification that may influence your decision. In a real-world engineering initiative, this sort of rapid re-assessment and iteration is very common, and in fact it is necessary as so many real problems do not have clean definitions and perspectives can shift often. A good engineering team needs to develop the skills to quickly assess and address needed changes.

Recall that some of the design assessments and considerations that were suggested for each PERSEID layer. To repeat, they are:

Performance

- Rate of false detects and false non-detects.
- Data

Socio-cultural

- Privacy
- Noise
- Unintended consequences

Policy/Regulatory

- Canadian Aviation Regulations[i]
- Trespass Act[ii]

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- Offences against Air or Maritime Safety[iii]
- Privacy laws[iv]
- Impact of crashes on ecosystems
- Noise pollution
- Battery life

Environmental

One of the more obvious metrics for your project would be rate of false detects and false non-detects. What other metrics would be of interest to you? Think of these as the outputs of the system. What information would you or others be interested in? For each metric assign a single PERSIED layer which you believe best corresponds.

PERSEID: **P**erformance + **E**nvironmental + **R**egulatory + **S**ocio-cultural screening for **E**ngineering **I**ntegrated **D**esign

1. Battery Life : Environmental - Short-term battery life (how long one charge of the battery lasts). If the battery requires frequent recharging, more energy is wasted during the process compared to a more efficient battery. This can be measured by the time one charge of the battery lasts or the distance that is travelled in one flight. - Long-term battery life (how many recharge cycles the battery can take). If the battery loses its ability to recharge is a relatively short time period, it will have to be replaced more often which creates more of an environmental strain, both the disposal of the old battery and the manufacturing of a new one. This can be measured by either the amount of time the drone battery lasts, or the number of times the battery is recharged. 2. Privacy Concerns: Socio-cultural for Engineering Integrated Design - When measuring the privacy concerns, we are going to create a survey that creates an automated score and how good someone's privacy is. The surveys will include feedback on the drones via the resident; if they have a numerous amount of concerns, the survey score will be low and the system will be adjusted according to the feedback. This feedback is necessary for the system to have a minimal number of interruptions to the public. This metric best aligns with the PERSEID layer of Socio-cultural screening. Privacy concerns best fits with socio cultural screening as it takes others concerns and well-being into account. When prioritizing privacy concerns, we minimize the chances

of interrupting or flying over land that may have cultural constraints that would be affected by the drone.

3. Canadian Aviation Regulations: Regulatory

- Considering the regulatory aspect of our design we must abide by aviation laws. To assess the regulatory layer of the perseid method we will track the average number of infractions per trip. We would want to minimize the amount of total infractions.

4. Flight Range and Flight Path: Performance

- We can assess the performance of the drone's flight ranges and flight paths through the measurements of the flight durations and battery usage. The optimal flight path and range will minimize flight durations while maximizing battery life and avoiding environmentally sensitive areas, and restricted airspaces.

Consider three different source water quality monitoring system designs. The rate of false detects, false non-detects, crashes, and grounding due to weather, as well as the flight time between charges are listed below for each system design. Units have been left off on purpose.

Design	False detect	False non-detect	Crash frequency	Weather-related grounding frequency	Flight time between charges
Design 1	30	10	1	2	30
Design 2	10	30	5	6	60
Design 3	15	15	20	4	15

Which element of each design has the best performance? How do you prioritise these performance metrics to choose the best design? Why? Think about this from your stakeholders' points of view. Which design do you think each of them would rather have implemented, and why? (Note that economics are *not* a consideration in this course – more on economics in third year!)

Stakeholder 1 – Water Treatment Plant: "Early detection of harmful algal blooms will provide the warning we need to adjust the treatment process so that we can deliver safe water to our customers."

• Stakeholder 2 – Environmental Group: "Drones crash all the time. What happens if one crashes in an environmentally sensitive area? I heard that a drone crashed in Florida and damaged the eggs of an endangered species of turtle."

• Stakeholder 3 – Government: "It will be important that this technology is deployed in a way that does not interfere with aviation, trespassing, or privacy laws."

• Stakeholder 4 – Local Resident: "I come to the lake to get away from it all. The sound of drones flying overhead really bothers me."

• Stakeholder 5 – Younger Population: "We are very worried about degrading water quality, and how it will affect our futures."

Group opinion: In terms from most effective design to least, we decided to have the order of design 1, design 2 and then design 3. When analysing the drone, the first metric we looked at was the false non-detects. We wanted to minimize the false non-detects of the drone mainly as the water quality is the main concern of this objective. A false non-detect will harm the quality of the water greatly compared to the other metrics. Our goal is to create safe-drinking water for the residents around the lake; however, false-non detects defeats the purpose of the goal. The second metric that we are prioritizing is minimizing the crash frequency. Considering the environmental aspect of PERSEID drone crashes can potentially harm ecosystems and environmentally sensitive areas. Because economics are not a concern, false detects of clean water is not an issue. Once there is a false detect, the water would have to be manually tested, which would only cost time and money. False detects might cause some distrust in the system if the frequency is too high, which could become a socio-cultural issue.

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Stakeholder 1: The water treatment plant stakeholders will prefer Design 1 as it minimizes the false non-detects which will enable early detections of algal blooms so that they can adjust the water treatment processes and deliver safe drinking water to their customers.

Stakeholder 2: The environmentalists would want to prioritize minimizing crash frequency therefore they would most likely choose design one because it has the lowest crash frequency, and it is only flying within 30-minute intervals potentially reducing the chance of causing harm to environmentally sensitive areas. This stakeholder would want to choose design 1.

Stakeholder 3: Would want to minimize both the crash frequencies and the flight time between charges. The minimization of the crash frequencies would prevent the drone from crash landing into any government restricted areas. The minimization of the flight time between charges would take the interference of aviation into account. The drone would interfere with the aviation around it less if the flight time duration is low. This stakeholder would choose design 1 as it averages out both the flight time between charges and the crash frequencies.

Stakeholder 4: The residents or frequent lake visitors would prioritize minimizing flight time between charges so that they can enjoy the lake without the sound of constant drone flight, therefore they would choose design 3 since it has the shortest flight time of 15.

Stakeholder 5: For the younger population and students, the future of the water quality is the biggest concern, so the amount of false non-detects is the most important and Design 1 would be chosen. This design has the lowest amount of false-non detects, along with the lowest crashes and an average flight time, which benefits the system environmentally too.

6

In systems engineering “quality attributes” are used to evaluate aspects of the system which are difficult to measure. For example, we have all had experience with products which are easier/more intuitive to use than others (think about websites and phone apps), but how would an engineer measure useability?

Take a look at this article: List of system quality attributes

Which attributes do you think apply to this project? Choose five, and state what each attribute is explicitly referring to in the context of a source water quality monitoring system.

1. Accuracy
   Accuracy in the context of water quality monitoring system would be referring to how accurate the data monitored by the programmed drones.

2. Debuggability
   Errors and bugs are not uncommon problems when it comes to drone operation. Debuggability would be referred to the system’s ability for the executional group to debug and fix the occurred and potential problems.

3. Efficiency
   Efficiency is usually referring to the organic combination of short time-consumed and more work-done. In the scenario of water quality monitoring system, efficiency would be referring to using the least cost of purchasing and maintaining drones to acquire the water quality data.

4. Modularity
   Modularity in the context of water quality monitoring system would be the reference towards the combination of multiple design components. Higher modularity would mean higher flexibility within the components that the group need to put together. From instance, the component of system would include drones’ hardware, algorithm of drone operation, and drones’ maintenance. Each part has its own technically independent characteristics, and meanwhile serves as necessity for the entire system to be operate.

5. Safety
   Safety within water quality monitoring system would means the safety of drones and the safety issue caused by the drones. Drone’s safety can be ensured with selected hardware design and the safety issue caused by the drone can be eliminate by proper design of the route taken and algorithms.

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Up to this point you have been looking at performance metrics, or outputs, of the system. What are the inputs? What describes your design and operating protocol / guidelines? What are the parameters?

- Images:

The images are the main input of the system. The images gather all of the data for the detection algorithm and allow the ability to detect the algae blooms, which is the main objective. The image resolution, followed by the image frequency, would be the main parameters that would determine the effectiveness of the system.

- Privacy surveys:

Surveys will be used to gather public inputs on the performance of the monitoring system in terms of privacy ratings. Privacy ratings associated with certain geographical locations will affect the flight paths or operational altitude of the drones, e.g. if the privacy ratings in a certain location is poor, then the drone will either have to fly around the location or fly higher. Parameters for the privacy surveys include; the number of surveys, the frequency with which surveys are conducted, the privacy ratings obtained from the surveys.

- Weather updates:

The weather can possibly affect the protocol of our system as it can delay a path, change the path or even prevent the drones from flying on specific days with bad weather. Parameters for this input can possibly be the wind speeds, rain, snow, etc.

- Geographical information (ex. avoiding environmentally sensitive areas):

This input shows that our operating protocol would include avoiding areas that we should not fly over. A parameter would be how accurate the map for the drone is (ex. indicating all restricted areas and avoiding them), and the GPS system on the drone to get the drones location and distance to prohibited locations.

To assess designs and operating protocols/guidelines formally, you will be implementing machine learning and error models provided. Applying these models and refining your design will start next week and will be ongoing over the next few weeks. Start by thinking about your vision for your system. What assumptions will you need to make? For example, an assumption could be:

- The client/owner/user will be responsible for data management
- Operators will ensure the system is grounded during inclement weather – the UAV does not need to be equipped to measure wind speeds/follow weather reports itself

These will help you scope your design. List some assumptions (you can relax/remove them later).

- Weather will be assessed before the drone flight and will be operated only in adequate flight conditions. Along with this, the drone will only operate during the day and when the light levels are high enough to get quality images.
- Algae blooms only form in the summer months, so extreme cold and snow is not needed to be factored into the battery life or drone operation
- There will be an operator to release / capture the drone before / after flights, along with repairing the drone and recharging the batteries
- Once the drone is in the air, the system is fully automated and will return to the same landing location once the flight is done (or earlier in case of emergency)
- Once a detection is made, the appropriate people / company will be notified in a timely manner to further investigate the issue

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Preparing for Milestone 1 (30 minutes)

The Milestone 1 report requires you to review all of the conclusions and decisions that you have come up with so far then integrate them into a single cohesive document that offers a clear articulation of the engineering system that you will be working with. Take the time in this Design Studio to see if your conclusions are clear and complete enough to continue to make good design decisions. You should also discuss whether you are content with the emerging concept. One good way of testing the clarity of thought and cohesiveness of conclusions is to write a compact summary. Complete the following:

We chose _Lake St. Clair_ as our geographical area.

Based on initial assessment and consideration of stakeholder input, some specific and particularly difficult challenges that we need to address are:

Potential Challenges:

Challenge 1: Drone operating system: parameters: Flight Path / Battery Life / Privacy / Environment. This will be a particularly difficult challenge due to the various parameters and stakeholder input. For instance, the stakeholders want to preserve privacy of nearby residential areas and preserve environmentally sensitive areas this means that we will have to change the flight path avoid these areas which may require a longer lasting battery. Developing and producing battery's is not an environmentally friendly task. Balancing each input and output so that every stakeholder is satisfied will be challenging since every change is a moving part and can negatively affect another aspect.

Challenge 2: Algae bloom detection: parameters: False detects, Image processing, camera. Developing an effective algae bloom detection system will be a difficult challenge. This will require a good camera which could decrease functionality of the drone due to weight. Also determining how to decrease the amount of false detection and false non-detection will be difficult as it is open-ended since its effectiveness is based on a machine learning algorithm.

To resolve and reconcile these challenges, we will be emphasizing the following key design parameters for each of the PERSEID design layers.

- According the groups' duty of implementing the PERSEID the following four aspect hold vital importance when executing.
- For performance consideration, the key design parameter of efficient navigating programming would be emphasized.
- For environmental consideration, the key design parameter of monitoring errors would be emphasized.
- For regulatory consideration, the key design parameter of flight height and route would be emphasized.
- For socio-cultural consideration, the key design parameter of residential acceptance would be emphasized.

After completing this portion if the combination of your answers to each portion reads well and makes sense then you have a good start. If you notice that some elements seem out of place or do not connect well with the others, you may want to revisit that element with the team.

If the above is in good shape, it becomes a great first step in composing the Executive Summary of the Milestone 1 report and a will help you to more efficiently write up the remainder of the report.

Submission Instructions

Upload a *.PDF copy of the Wk-4 - Synchronous Design Studio 4 Worksheet to the Avenue Dropbox titled Synchronous Design Studio Week 4 by Feb 6th

- Use the naming convention: Tut#_Team#_SynchDS4.pdf

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[i] https://tc.canada.ca/en/corporate-services/acts-regulations/list-regulations/canadian-aviation-regulations-sor-96-433
[ii] https://www.ontario.ca/laws/statute/90t21
[iii] https://laws.justice.gc.ca/eng/acts/C-46/page-7.html#h-116204
[iv] Office of the Privacy Commission of Canada, Drones in Canada, Office of the Privacy Commission, Gatineau, QC, 2013. https://www.priv.gc.ca/information/research-recherche/2013/drones_ 201303_e.pdf.

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Week 5: Synchronous Design Studio

Source Water Quality Monitoring Project
Modeling – Performance Layer in PERSEID

OVERVIEW

This activity helps you identify and incorporate some of the technical constraints related to the operational characteristic of the drones and the desired performance metrics. From the Week 5 Asynchronous activity, all team members should now have some level of familiarity with the function of the machine learning module as well as the overall accuracy performance metric. Additionally, as a group, you should have some capacity to confidently discuss how the effects the size of the training database may play a role on the accuracy of the system.

In this Synchronous studio, you are asked to use/adapt the model to begin answering some of the key concerns for the design with emphasis on the technical PERFORMANCE of the design. You should recall the various discussions you have had in previous studios in terms of any constraints, assumptions, and key parameters as they will be helpful in assessing merits of design ideas.

KEY KNOWLEDGE PROVIDED

Confusion Matrix and Accuracy

Let us first introduce some of the essential definitions of the performance metrics and establish relationship to terms false detects and false non-detects. Let us consider a case of training database that has 1000 images so that 800 images have no algal blooms and 200 images show algal blooms. Let us say that out of the 800 no-algae images we correctly identify that 750 of them do not have algal blooms and let us say that in 200 of algal images we correctly identify that 180 of them have algal blooms. Obviously in this case we made two types of errors. The number of false detects or false positives (FP) is 50 and number of false non-detects or false negatives (FN) is 20. Opposed to this are true positives (TP) and true negatives (TN) where we assumed that term positive refers to the presence of algal bloom. We often summarize these results in something we call a confusion matrix:

Truth algae, Decision algae = 180 (TP)	Truth algae, Decision no algae = 20 (FN)
Truth no algae, Decision algae = 50 (FP)	Truth no algae, Decision no algae = 750 (TN)

The overall accuracy is then defined as (TP+TN)/total = (180+750)/1000=93%

Step 1 (30 minutes): Close Gaps in Understanding

First, survey everyone in the team and determine if there are any gaps in understanding of the model and definition of accuracy. If a member needs a bit of guidance, take the time now to help that team me mber align their understanding with the team. Then as a team discuss what are some of the drone operating characteristics that may affect the performance of your system. Some possibilities include drone velocity, robustness to environmental conditions, flight altitude, etc.

Definition of accuracy: how effectively the model can predict if an image contains algae or not

Drone Operating Characteristics

- Drone operating altitude requires an optimal balance between detail and how much of the water in within the frame of the image.
- Drone velocity and stability are important to capture a highly detailed and quality image for future use by the algorithm.
- Type / Quality of the camera on the drone will determine the resolution and size of the captured images
- Battery life of the drone will affect how many images can be captured in a given amount of time, affecting the sample data fed into the Machine Learning algorithm.

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Step 2 (30 minutes): Explore system options related to the performance of the model

Now consider the following three types of drones and discuss as a group which two of the enclosed three choices would be the best option for the region you selected in previous design studios. Justify your choices. Note that flight stability refers to robustness of your drone to weather conditions such as wind i.e., your ability to control and predict exact location of the drone in windy conditions.

Name	Speed	Image quality	Flight stability	Battery Life	Ability to store/transfer images
Flying fortress	Low	Medium	High	Low	High
Hawkeye	High	High	Low	Medium	Low
Great Horned Owl	Medium	Low	Medium	High	Medium

First - Great Horned Owl

For the region we selected, the best drone we choose was the Great Horned Owl. The main aspect of the drone we focused was the battery life as we want the drone to be able to fly all around Lake St. Claire (due to its large size). This makes this drone the best option out of the 3 as the battery life is high. When looking at the flight stability, we considered it as a second priority because of the environment we are flying in. Since we are flying in the ideal weather conditions majority of the time, medium flight stability is adequate. The ability to store/transfer images wasn't a high priority for us because we assumed that the images can still be transferred; however, it will be slower. The drone will not be flying throughout the whole day, so there is a lot of time for the images to transfer while the drone is at its station. We did not see the image quality as a very big factor as we believe we are able to deal with bad image quality as the water will be distinct different colours when algae blooms in it or not. Finally. we also didn't really look at the speed as an important factor as the high battery life will account for this.

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Second - Flying Fortress

High image quality ensures the outcome of algorithm is more promised for the machine's sampling and learning. Flying fortress's high image quality and ability to store and transfer boost the efficiency for water condition monitoring, which results in it being our group's secondly preferred option for this project. What's also makes it one of our most favorite drone is its high stability, this characteristic serves a vital purpose of giving the group a secure operation with low possibility to lose drone in an operation. Although the speed of it isn't its strength, but our priority most lies in the aspects of image qualities.

Third - Hawkeye

Flight stability was determined to be one of the most important parameters in measuring the overall ability of a drone, and the Hawkeye drone has a low stability. This, along with the medium battery life makes it the worst performing drone. The characteristics that this drone excel at, drone speed and image quality, were determined to be less important because without a stable image, a high quality image is not possible, and without a high battery life, the speed of the drone is not important. The high speed could also lead to worse overall control of the drone and worse image quality because the drone moves more rapidly.

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Step 3 (30 minutes): Explore model options

This design challenge and sample machine learning model may have different variations and parameters that may affect your final design choices. Although the design of your own machine learning module is out of the scope for this course consider the following different algorithms: deep neural networks (DNN), recurrent neural networks (RNN), and convolutional neural networks (CNN). Note that computational time for these algorithms and their robustness to noise levels are not part of this discussion and will be included in a design studio later in this course.

Using the table below discuss as a group which of the following algorithms you would choose and explain/justify your reasons. Discuss the possibility of using multiple algorithms to improve the overall accuracy. List possible suggestions of how you would make the decision if the different algorithms cannot agree whether a particular lake image contains an algal bloom.

Model Name	Database Size	FP	FN
DNN	**~10000 images**	**1%**	**3%**
DNN	~ 1000 images	3%	7%
DNN	~ 100 images	29%	41%
RNN	~ 10000 images	5%	2%
RNN	~ 1000 images	10%	6%
RNN	~ 100 images	21%	20%
CNN	**~10000 images**	**4%**	**1%**
CNN	~1000 images	9%	12%
CNN	~100 images	39%	41%

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First Model (CNN with 10000 images):
We decided to choose the model of CNN with the highest Database size as the computational time for the algorithm does not matter so we want the largest number of images taken. We also wanted a lower amount of false negative rather than false positives so we can balance the detections between both drones.

Second Model (DNN with 10000 images):
The second model that was chosen as a backup to the first was the Deep Neural Network with the largest dataset. This NN has the lowest number of false positives, which complements the Convolutional NN with the lowest number of false negatives and slightly higher false positives. This allows both false positives and false negatives to be covered with as much accuracy as possible.

In the event that the two models produce contradictory predictions, any positive algal bloom detection, whether that turns out to be real or a false positive, will be prioritized and the appropriate personnel will be sent to manually test the lake for algae.

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Step 4: Summary of current state

Based on today's work, summarize the current state of your thinking and to the best of your ability, state your design recommendations with respect to Objectives 2, 3 and 4 from your original project module. Note, this is not your final conclusion. You will continue to iterate and refine your thoughts. But if you were to have to conclude today based on these activities, what would your recommendations be?

Objectives:

2. Design a low height aerial monitoring system to monitor drinking water sources (i.e., lakes) for algal blooms including image resolution, image frequency, impact of weather conditions, etc.
3. Conduct an error analysis
4. Use the PERSEID method to discuss operating conditions and power considerations.

Based off today's design studio, we want to create a low-heigh aerial monitoring system with the following well-considered criteria. Flight stability and battery life being the highest priorities, followed by image quality. These characteristics serve vital importance for the entire system to operate with high accuracy and operational efficiency.

The battery life of the drone is an environmental concern because the production of batteries takes many resources, and the improper disposal of batteries is harmful to the environment. The privacy concerns of the drone will be addressed by surveys asking the surrounded population if they feel comfortable or have any conflicts with the drone operation. For any regulatory concerns, mainly the Canadian Aviation Regulations, the drone will always operate within the regulations provided and this will be taken into account within the algorithm created. For the performance concerns, we have many metrics we are going to consider such as the flight range and flight efficiency.

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The speed of the drone does not affect the performance of the drone too much because a longer battery life is a higher priority because the longer the drone is airborne, the more images that can be collected. The drone will only operate in close to ideal operating conditions (low wind, no rain, etc.) and will have enough down-time to transfer images to the machine learning algorithm.

The algorithm will be trained on a large sample size, using two different neural network structures, deep neural network and convolutional neural network. These first algorithm minimizes false positives and the second minimizes false negatives, and they will check the outputted results against each other. If any positive output is detected, whether there is a disagreement between algorithms or not, the lake will be manually checked.

Submission Instructions

Upload a *.**PDF** copy of the Wk-5 - Synchronous Design Studio 5 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 5** by Feb 13th

- Use the following naming convention: **Tut#_Team#_SynchDS5.pdf**

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Week 6: Synchronous Design Studio
Source Water Quality Monitoring
Socio-Cultural Considerations

Overview and Goals

This activity is a continuation previous weeks' activities using the PERSEID methodology to refine and optimize your design options. Based on the asynchronous activity this week, your team should now come together and reconcile each member's thoughts into a single, cohesive set of conclusions. At this point it is important to differentiate between the terms "socio-cultural considerations" and "socio-cultural constraints". Merriam-Webster defines consideration as "a matter weighed or taken into account when formulating an opinion or plan" and constraint as "a constraining condition, agency, or force". We have used the term "consideration" thus far, as the factors you identify should be taken into account when formulating your design. A constraint is a more rigid boundary that you cannot cross. Your team may decide, either on your own or based on input from a community, stakeholder, etc., to treat some of the considerations you have identified as constraints. Please use the terms "consideration" and "constraint" carefully.

One more note – in the steps below, the term "design" refers to both the physical system components and the recommended operating conditions.

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Step 1 – key issues (30 minutes)

a. Based on the article by Sandbrook (2015)[1] and each group member's thoughts and research, what are the most important socio-cultural considerations (i.e., the considerations that your team members have the strongest agreement on)?

1. One socio-cultural concern with our water monitoring system is the privacy concerns of our stakeholders. The residents living around the water we plan on working on have stated that they don't want the noise of the drones disturbing them during their daily activities. The consequence of us disturbing the public can be the possible shutdown of our mission. This consequence would be an unintended consequence because as a team, we want to help the public rather than giving them more problems. This consequence can negatively impact the team and the residents

2. We can also discuss the data security of the information collected from the drones. In many situations, people will be concerned about their data being leaked; however, the only situations it can be acceptable in is if the government needs it [1]. We want our drone's data to be as secure as possible as the images captured may include something that we cannot share [1]. If the images were taken out of our data base into wrong hands, that can violate the ethics and morals of our objective [1]. This consequence would be an unintended consequence as we cannot predict whether our drone can be hacked or not. In order to account for this unintended consequence, we have to improve our security algorithm with our drone to ensure that no one hacks into the system. This also would have a negative impact on our water-monitoring system as it affects the overall performance of our system.

3. Another social cultural impact that we need to look at is the noise pollution caused from our drones. According to human ethics, drones should be used to legal and moral reasons only [2]. If we cause a significantly large amount of noise pollution, that can violate the morals we want to follow [2].

4. Better Public Health – The drone system has the main objective to detect algae within the lake, which would reduce the number of times algae infected water makes it into the community drinking water.

[1] Sandbrook, C. The social implications of using drones for biodiversity conservation. *Ambio* 44, 636–647 (2015). https://doi.org/10.1007/s13280-015-0714-0

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b. Are there any significant disagreements among your group members regarding socio-cultural considerations? Please list these here, together with the reasons behind your disagreements.

- One area of disagreement on socio-cultural considerations was determining whether drone noise pollution or privacy concerns was more important, and which should be prioritized.

Arguments for prioritizing noise pollution was that it directly addresses a stakeholder's concerns and easier to address than privacy concerns as active and passive noise filtering technologies can be easily employed to minimize the noise, while privacy concerns would require rerouting of flightpaths (requiring more battery life), or complex algorithms to blur people's faces.

When looking at the privacy aspect of the social cultural implication approach, we wanted to prevent any confidential information that the residents want to keep private from being used. We also want to blur the faces out any residents that are included in our images. Noise cancellation can increase the cost of our drones and the maintenance for our drones, which we want to reduce as much as we can. Another argument to consider is that if we prioritize privacy, by avoiding nearby residential areas, reserves and populated areas then noise won't be a concern if there is no population nearby to hear it.

Winner : Privacy concerns

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Step 2 – changes in thinking (30 minutes)

Now that you have had several weeks of deliberation as well as this special focus on socio-cultural considerations, have any of your thoughts shifted when considering the key design regarding technical system specifications or operating conditions? Does this stage challenge anything that you concluded in the performance stage of PERSEID?

- Community safety is one of the highest objectives of the drone system, and decisions with the system would be made to optimize the safety and security of the public. The priority of these community safety decisions has become more and more important throughout the weeks. Many of the other socio-cultural impacts are more long-term, such as the public's opinion on the drone security. The long-term consequences of the design choices will still be considered in the decision-making process but may become out of the scope if the required solutions are too demanding to be completed in a short amount of time. The system would be created to match and agree with the public's opinions on the drone security as much as possible (with info gathered from research), but the privacy surveys would be too delayed of a decision choice to be made within this project. Deciding what should be in and out of the scope of the project has been an ongoing process and has changed throughout discussion.

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Step 3 – model adjustment (15 minutes)

Last week your group completed a machine learning exercise and then provided a qualitative discussion on the expected performance of the algorithm as a function of several parameters. We will be investigating the impact of design parameters on performance further in the coming weeks. However, based on what you have discussed so far, is there be any way that you could adjust your design parameters to augment and mitigate positive and negative socio-cultural considerations, respectively? Please discuss.

In the beginning of the project, our group's priority lies into make sure the system as all has the most accurate and effective outcome. As time goes by, we found that in reality there are more aspects that we need to consider more than just the technical outcome. During the mid-way of our design for monitoring project, we add some distinct aspects of socio-cultural factor in our considering. This does lead to some of our theoretical technical outcome compromised to some extend. Further down the road of being a ethical engineer, we add more and more considering upon our project. And one of the most essential improvements we did in this part, is that we are putting effort to work on a mutually beneficial method to finish the mission and satisfy the socio-cultural stakeholders. Previous strategy of comprising was considered a less efficient use of the given condition and constrains. Collectively re-assign and re-prioritize the aspects of our drone design and algorithms design not only make our team's design more reality-based and also make our teammates more experienced in the further field of the industry

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Step 4 – Where are you now? (45 minutes)

Now that you have completed PERFORMANCE and SOCIO-CULTURAL layers of the PERSEID method, what do you need to know to be able to make design decisions? Decide how you will get this done. Consider assigning tasks to each group member, and then reconvening to revise and refine your design. It is normal for the team to revisit past decisions and make changes. This is the design iteration.

In terms of drone performance, we will need to know the drone's performance in terms of speed, image quality, flight stability, battery life and ability to store/transfer images. We decided that the first prioritize was battery life, followed by flight stability, and image quality. These would ensure for maximized drone performance.

For machine learning performance we will need to know what machine learning models to use, these involve the CNN (Convolutional Neural Network) model the DNN (Deep Neural Network) model. Going forward we decided to employ a hybrid combination of the CNN and DNN model. The first algorithm minimizes false negatives and the second minimizes false positives, and for improved accuracy they will check the outputted results against each other.

Going forward with making design decisions, we must consider the performance and socio-cultural consequences of the choices made. We need to consider the socio-cultural impact, privacy concerns when making new design decisions. For example, when making decisions regarding flight path and drone altitude we must consider how the decisions will affect stakeholders that prioritize their privacy. We have also discussed a system that blocks faces from images.

When looking at decisions, we now know that we need to take the security of our data very seriously. We do not want information that should be private being hacked or put out (which would be an unintended consequence). This would have great negative effects on our project, and we want to avoid this at all costs. This would also fit into the privacy concern aspect of our stakeholders, and we want to make this a main priority.

Noise pollution should be considered with future decisions because if the system is too noisy, both the public and the stakeholders many be upset. The choices that can potentially affect the noise of the drone system must be analyzed to see if the addition / modification would add too much noise, and a balance of the performance of the drone and the noise of the system must be achieved.

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Submission Instructions

Upload a *.PDF copy of the Wk-6 - Synchronous Design Studio 6 Worksheet to the Avenue Dropbox titled Synchronous Design Studio Week 6 by Feb 20th.

- Use the naming convention: Tut#_Team#_SynchDS6.pdf

Works Cited

[1] C. Sandbrook, "The social implications of using drones for biodiversity conservation," *Ambio*, vol. 44, doi: 10.1007/s13280-015-0714-0.

[2] A. van Wynsberghe and T. Comes, "Drones in humanitarian contexts, robot ethics, and the human-robot interaction," *Ethics and Information Technology*, vol. 22, pp. 43–53, 2020, doi: 10.1007/s10676-019-09514-1.

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2

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Week 7: Synchronous Design Studio
Source Water Quality Monitoring
Regulatory Considerations

Overview

This activity is a continuation previous weeks' activities using the PERSEID methodology to refine and optimize your design options. Based on the asynchronous activity this week, your team should now come together and reconcile each member's thoughts into a single, cohesive set of conclusions regarding the regulatory considerations that apply to your design.

Last week, we differentiated between the terms "consideration" and "constraint". Note that a regulation is a hard constraint – your design must comply with regulations if it is to be implemented. However, the widespread use of drones for monitoring is an emerging area, and the regulatory landscape for drones is likely to become stricter in the (not so distant) future. Your team would be wise to ensure *sustainability* of your design by i) considering the kinds of regulations that may be in place in the future; and ii) ensuring that your design complies (or will be able to comply with minimal modifications). This type of information can be found by looking to other jurisdictions that are further ahead with this technology.

Additionally, in Week 5 you were given two Python codes for identifying a particular structure in images contained in a dataset: a) Terrain detecting water vs. desert areas; and b) Algae detecting lakes with and without algal blooms. This week you will be expected to explore the impacts of i) data structure organization; and ii) dataset size on the overall accuracy of the system.

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Step 1 - Initial assessment of the REGULATORY layer (30 minutes)

a) Based on each group member's research, what are the most important regulatory constraints and considerations (i.e., the considerations that your team members have the strongest agreement on)?

- 5.6 km from airports

- Drone must fly below 400 feet or 122m and 100 feet (30 m) above any building or structure.

- The drone must always be no closer than 100 feet (30m) from bystanders, expect crew of operating personnel

- causing damage to an aircraft in service that renders the aircraft incapable of flight or that is likely to endanger the safety of the aircraft in flight is a criminal offence against air or maritime safety:

- The maximum acceptable concentration (MAC) for the cyanobacterial toxin microcystin-LR in drinking water is 0.0015 mg/L

- Drone must remain within Canadian Domestic Airspace, and not enter restricted airspace, for the entire operation

- All pre-flight, take-off, launch, approach, landing and recovery procedures must be established and properly executed

b) Are there any significant disagreements among your group members regarding Regulatory considerations? Please list these here, together with the reasons behind your disagreements.

- One disagreement we stumbled upon is the rule of staying inside Canadian Domestic Airspace. In our specific case, the lake does cut through the border; however, we plan on keeping the drones flight path close by shore, so this would not be too much of an issue. We also plan on implementing an algorithm that would avoid crossing the border, so this law is not too important to this mission.

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Step 2 – changes in thinking (20 minutes)

Now that you have had several weeks of deliberation as well as this special focus on regulatory issues, have any of your thoughts shifted when considering the key design decisions regarding technical system specifications or operating conditions? Does this stage challenge anything that you concluded in the performance or socio-cultural layers of PERSEID?

- The placements of our stations may also need to be changed because we need to consider how far we are from airports or any other no-fly zones in the vicinity.

- Our flightpath can possibly change because of airports and the regulation of not crossing the border. The flight path might also change because of the standard amount of space we need between the drone and bystanders. Some areas may not allow the drone to fly through them without violating this constraint, so that will need to be taken into consideration.

- There are additional operational altitudinal and latitudinal constraints as the drones will be limited to a maximum altitude of 122m and a minimum distance of 30 m above buildings. For latitudinal constraints, the drones must come within a minimum lateral distance of 30 m from any bystanders.

- This does challenge the PERSEID layer of performance as we need to consider the aerial and flight path limitations when designing our drones. This can either affect the performance layer in a positive or negative way, depending on if we create a more efficient flightpath based on what we need to avoid. This also does affect the socio-cultural considerations we made as we need to implement a physical component that makes sure our drone follows the altitudinal and latitudinal limitations, which benefits our socio-cultural approach on this objective.

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Step 3 – model adjustment (15 minutes)

For this PERSEID step, would there be any way that you could adjust your source water quality monitoring system design to include constraints and considerations identified this week? If so, please suggest any strategies for doing so. If not, why are the regulatory constraints and considerations that you have identified consistent with the current design?

You may need to modify your strategies multiple times as you further explore your design in future sessions. List the relevant design parameter(s) associated with each constraint or consideration, and briefly mention your strategies for employing these considerations in your design.

The regulatory constraints and considerations do not affect the machine learning algorithm because most of the regulatory laws affect the physical location of the drone and not the digital aspect of the project. The only constraints that may possibly affect the machine learning algorithm is privacy laws when collecting and analyzing the images. This consideration falls more under a socio-cultural concern rather than regulatory because the drone operates overtop of a lake, there are almost no people where their privacy could accidently be violated, and even if an image was taken of them, the image would have no legal consequences because the drone is operating in a public space with positive intentions behind the operation.

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Step 4 – Where are you now? (30 minutes)

Now that you have completed the PERFORMANCE, SOCIO-CULTURAL, and REGULATORY layers of the PERSID method, what are your current design decisions? It is normal for the team to revisit past decisions and make changes. This is design iteration.

Physical system components:

1. Battery Life: Environmental

- Short-term battery life (how long one charge of the battery lasts). If the battery requires frequent recharging, more energy is wasted during the process compared to a more efficient battery. This can be measured by the time one charge of the battery lasts or the distance that is travelled in one flight.

- Long-term battery life (how many recharges cycles the battery can take). If the battery loses its ability to recharge is a relatively short time period, it will have to be replaced more often which creates more of an environmental strain, both the disposal of the old battery and the manufacturing of a new one. This can be measured by either the amount of time the drone battery lasts, or the number of times the battery is recharged.

2. The Algorithm: Performance and Socio-Cultural

Will be trained on a large sample size, using two different neural network structures, deep neural network and convolutional neural network. These first algorithm minimizes false positives and the second minimizes false negatives, and they will check the outputted results against each other. If any positive output is detected, whether there is a disagreement between algorithms or not, the lake will be manually checked.

3. Flightpath: Performance, Socio-cultural & Regulatory
Given the refined operational latitudinal and altitudinal constraints, the flightpath algorithms will need to be designed to account for constraints such as flying 30 m above buildings, and 30 m laterally from bystanders. This entails that our drone monitoring system may need to be capable of identifying buildings and bystanders so as to decide the best course of action.

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Step 5 - Explore the trade-off between database size and overall accuracy (35 minutes)

In Week 5 you were given a Python code and the corresponding database compiled into the Python notebook Algae. By now you should have identified that the overall accuracy of the system is very dependent on the size of the database available for training.

In this session you are required to share your individual findings with your teammates and brainstorm to:

1. Explore and find the effect of different training/testing ratios by creating your own test/train folders using the database of lake images available on A2L.

- The training accuracy on the larger database is much more efficient as seen on graphs. There is a relationship between how large our database is and how smooth our validation and training numbers are. We want a larger training set because the training set is what creates the algorithm.

2. Explore the trade-off between the database size and overall accuracy (qualitative more than quantitative). Explore difference in the performance between the Algae and Terrain notebooks (the latter of which contains a much larger number of images).

- The trade-off between database size and overall accuracy is proportional. The more images you can train the algorithm off, the more accurate the algorithm will get. The only downside to the larger database size is the time to run the algorithm. On the graphs, the orange line is much smoother with a larger database than the smaller database. The validation is much stronger and efficient on the lager database.

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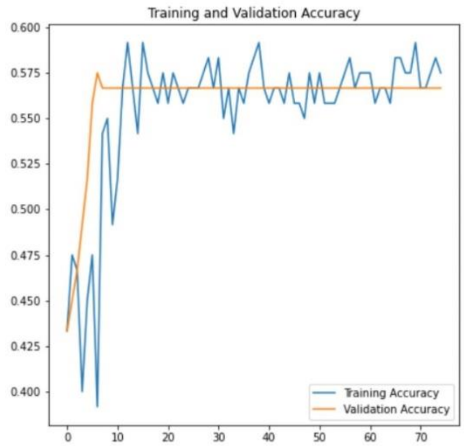
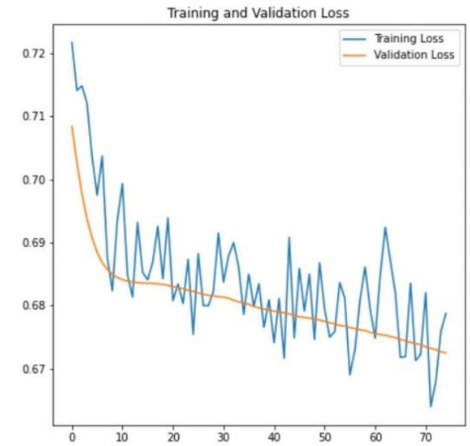
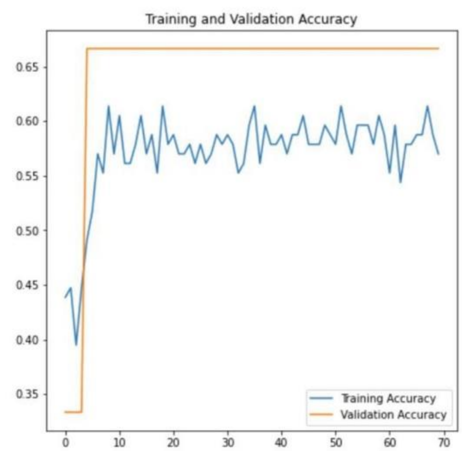
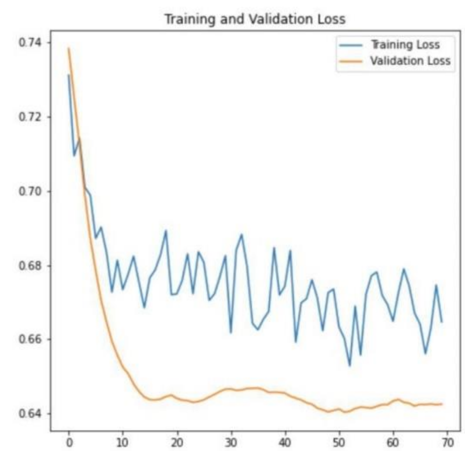
Larger Database:





Smaller Database:





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3. List other reasonable and feasible recommendations for improving the accuracy of the algae identification process.

- Image quality and clarity will provide better images to the algorithm
- Clear weather and suitable operating conditions such as sunny, daytime, low wind
- Correct height of drone to get wide enough view and enough details within the images
- Collect images from many different sample locations

Submission Instructions

Upload a *.**PDF** copy of the Wk-7 - Synchronous Design Studio 7 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 7** by March 6th

- Use the following naming convention: **Tut#_Team#_SynchDS7.pdf**

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Week 8: Synchronous Design Studio

Source Water Quality Monitoring

Environmental Considerations

Overview

This activity is a continuation previous weeks' activities using the PERSEID methodology to refine and optimize your design options. Based on the asynchronous activity this week, your team should now come together and reconcile each member's thoughts into a single, cohesive set of conclusions regarding the environmental considerations that apply to your design.

Step 1 - Initial assessment of the ENVIRONMENTAL layer (30 minutes)

a) Based on the article and group member's thoughts and research, what are the most important environmental constraints and considerations (i.e., the considerations that your team members have the strongest agreement on)?

The construction and manufacturing of drones have large economic, social, and environmental impacts that require keen attention to be paid. When building these drones, there are many environmental impacts that we need to consider.

- When looking at the drone, one environmental impact we need to take into account is the noise pollution. One of the any stakeholders clearly states that the noise will be a concern to the neighbourhoods around the source water; thus, we need to keep that as a priority during this objective.

- This team should also look into the wildlife impacts of the drone because the confrontation made between the drone and the animal may end up being fatal. According to the article, research states that there has been an increase of vehicle-wildlife collisions has been prominent throughout the recent years, so this team needs to reduce the chances of that happening.

- Moreover, we need to also take the CO_2 and air pollution impacts into account. When going through with this objective, the goal is to help and improve the environment rather than destroying it so we want to avoid this at all costs.

- Furthermore, we want to design the drone in a way where the materials used does not harm the environment (or at least reduce the impact of it). The materials used in components such as the blades or the battery can impact the environment greatly, so the goal would be to reduce that impact as much as possible. Another environmental impact we need to consider, which ties onto the materials is the ability for the drone to not crash because the amount of waste produced by the drone should be minimized.

b) Are there any significant disagreements among your group members regarding environmental considerations? Please list these here, together with the reasons behind your disagreements.

One disagreement our group had regarding the environmental considerations is how drastically they should impact our design and how important the environmental considerations should be when comparing to the other layers. We all agreed that performance should be the highest priority, but with the other three layers – socio-cultural, regulatory, environmental – there were disagreements with the importance hierarchy. Some group members believed that environmental concerns should be ranked as high as socio-cultural, while others thought that environmental should be considered the lowest.

Another disagreement we mentioned was the importance of the CO2and air pollution impacts. Some group members mentioned that the drones would not cause that much a CO2 impact so it should not be a priority. Although the drone may not contribute directly to the C02 impact due to it using electricity we must consider the C02 pollution created by transportation of materials and battery manufacturing.

Step 2 – changes in thinking (20 minutes)

Now that you have had several weeks of deliberation as well as this special focus on environmental considerations, have any of your thoughts shifted when considering the key design decisions regarding technical system specifications or operating conditions? Does this stage challenge anything that you concluded in the performance, socio-cultural, or regulatory layers of PERSEID?

Design of Drone

- Size, rotor speed, noise output levels and frequency

This aspect may affect the performance of our drone as the adjustments we make to keep the drone silent may affect the efficiency of the drone.

- Environmental impact from production and destruction of drone, specifically the battery

This also may affect our performance as different materials for a battery vary in performance standards, so this team needs to balance out the importance of performance and environmental impact when making this decision.

Flight Path

- Change flightpath to avoid environmentally sensitive areas

Depending on what our flight path comes out to be because of avoiding environmentally sensitive areas, the performance can be affected because we may be using more battery life than before these considerations. It can either go both ways if we the avoidance leads us to a shorter path or longer path. For example, due to the numerous flightpath limitations, flightpaths may become very complex and energy-inefficient such that the drones are not able to complete their tasks in a timely and sustainable manner, which could affect how well we are able to meet the stakeholder’s needs.

- Stay away from animal-heavy locations, fly away from locations with lots of birds.

Flight Conditions & Time

- Only fly when weather is favourable
- Fly during the day with enough light to capture high quality images

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Step 3 – model adjustment (15 minutes)

For this PERSEID step, are there adjustments that you could make to your source water quality monitoring system design to include constraints and considerations identified this week? If so, please suggest any strategies for doing so. If not, why are the environmental constraints and considerations that you have identified consistent with the current design?

List the relevant design parameter(s) associated with each constraint or consideration, and briefly mention your strategies for employing these considerations in your design.

After researching and consulting with various environmental-related articles, each member of our group found something that is consistent with our current design and some un-think-of parts in this specific PERSEID step. After discussing as a group to consider how environmental-friendly is our current design and how can we improve our design while maintaining its performance in the other aspects. One of the designs that we are consistent using and without modification would be utilizing more efficient number of drones to finish the monitoring assessment. Previously, this design was brought up to fit the socio-cultural requirement. And in term of environmental issue, efficient number of drones would also minimize the noise pollution, energy usage, and visual disturbance for human and wildlife. Studying various article is indeed beneficial for our team to ultimately design a flawless project in everyway. One of the environmental factors that we never think of before this week would be the drones' operation causing soil sealing. This environmental issue has the potential of negatively affecting the environment severely. And the cause of it can also be ignored easily. Utilizing multiple drones would required a platform like drones port to organize the drones. And building these port is the direct reason for soil sealing. Our current strategy would be building temporarily port for drones to reduce this relatively-newfound environmental issue.

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Step 4 – Where are you now? (30 minutes)

Now that you have completed the PERFORMANCE, SOCIO-CULTURAL, REGULATORY, and ENVIRONMENTAL layers of the PERSID method, what are your current design decisions? It is normal for the team to revisit past decisions and make changes. This is design iteration.

Physical system components:

1. Battery Life: Environmental

- Short-term battery life (how long one charge of the battery lasts). If the battery requires frequent recharging, more energy is wasted during the process compared to a more efficient battery. This can be measured by the time one charge of the battery lasts or the distance that is travelled in one flight.

- Long-term battery life (how many recharges cycles the battery can take). If the battery loses its ability to recharge is a relatively short time period, it will have to be replaced more often which creates more of an environmental strain, both the disposal of the old battery and the manufacturing of a new one. This can be measured by either the amount of time the drone battery lasts, or the number of times the battery is recharged.

2. The Algorithm: Performance and Socio-Cultural

Will be trained on a large sample size, using two different neural network structures, deep neural network and convolutional neural network. These first algorithm minimizes false positives and the second minimizes false negatives, and they will check the outputted results against each other. If any positive output is detected, whether there is a disagreement between algorithms or not, the lake will be manually checked.

3. Flightpath: Performance, Socio-cultural & Regulatory

Given the refined operational latitudinal and altitudinal constraints, the flightpath algorithms will need to be designed to account for constraints such as flying 30 m above buildings, and 30 m laterally from bystanders. This entails that our drone monitoring system may need to be capable of identifying buildings and bystanders so as to decide the best course of action.

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2

McMaster University

Operating conditions:

1. Privacy Concerns: Socio-cultural for Engineering Integrated Design

- When measuring the privacy concerns, we are going to create a survey that creates an automated score and how good someone's privacy is. The surveys will include feedback on the drones via the resident; if they have a numerous number of concerns, the survey score will be low and the system will be adjusted according to the feedback. This feedback is necessary for the system to have a minimal number of interruptions to the public. This metric best aligns with the PERSEID layer of Socio-cultural screening. Privacy concerns best fits with socio cultural screening as it takes others concerns and well-being into account. When prioritizing privacy concerns, we minimize the chances of interrupting or flying over land that may have cultural constraints that would be affected by the drone.

2. Canadian Aviation Regulations: Regulatory

- Considering the regulatory aspect of our design we must abide by aviation laws. To assess the regulatory layer of the PERSEID method we will track the average number of infractions per trip. We would want to minimize the number of total infractions.

3. Flight Range and Flight Path: Performance

- We can assess the performance of the drone's flight ranges and flight paths through the measurements of the flight durations and battery usage. The optimal flight path and range will minimize flight durations while maximizing battery life and avoiding environmentally sensitive areas, and restricted airspaces.

Which decision was the most difficult? Which screening layers do you think will be the most problematic in the upcoming PERSEID steps, and why?

The most difficult decision was determining the flightpath of the drone. The most problematic screening layers will be performance, environmental and socio cultural. These three layers will be problematic because when considering environmental and socio cultural concerns i.e.(privacy, environmentally sensitive areas) performance seems to decrease. For instance, if the drone is restricted from certain areas of the lake where there is algae beginning to form then the drone will not be able to gather images and thus decreasing overall performance. Another Example is the drone avoiding environmentally sensitive areas or privacy sensitive areas might require the drone taking longer paths requiring a larger battery or multiple missions to cover the lake.

Step 5: Preparing for Milestone 2 (15 minutes)

For the next milestone, you are asked to "provide a summary table showing the broad funnel constraints, short descriptions of specific considerations that you eventually used". Please discuss and decide as a group, what your table structure should be. How will you organize all of your past discussions to represent your design decisions clearly and concisely? Feel free to adapt any of the tables that you have been provided through the various Design Studio stages.

Our summary table should the following headers: Constraint Consideration, Description of Consideration, and Effects and Repercussions. An example of a row of the summary table could be a constraint consideration of environmental impact from the noise of the drone. The description of the consideration would include the causes of the noise (rotor size, rotor speed, location of flight), and the effects would include the environmental impacts from the noise pollution, the socio-cultural impacts from the disturbance to the community, and the performance impacts from modifying the size of the drone to reduce noise but also reducing flight efficiency. This table should keep the different design considerations separate and unique, while also easily being able to compare the causes and effects from each choice.

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McMaster University

Submission Instructions

Upload a *.**PDF** copy of the Wk-8 - Synchronous Design Studio 8 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 8** by March 13th

- Use the following naming convention: **Tut#_Team#_SynchDS8.pdf**

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 McMaster University

Week 9: Synchronous Design Studio

Source Water Monitoring Project

PERSEID Method: Design Matrix

Overview

In continuation of last weeks' activities on PERSEID methodology for refining and optimizing your design options, this week you are required to design matrix based decision to your design projects. You are required to share and discuss the criteria and design choices with your teammates and apply the necessary steps in making sure the important design options are taken into consideration in your designs.

Initial selection of design matrix

From your asynchronous activity conclusions, share with your teammates the main criteria and design configurations / design choices that you have identified. All teammates should review others' suggestions.

List the criteria that your team members have the strongest agreements on. Aim for at least 3 criteria.

1. The drone performance should not be lowered too much by other factors, performance is still the highest design consideration. Other considerations, such as socio-cultural and environmental, are still important, but if the drone system does not perform as intended or to a required level of performance, the whole system would fail.
2. The Battery life should last for a long duration. A long-lasting battery will maximize performance of the drone.
3. The drone's flight stability and flightpath is another important factor that should be prioritized. The stability of the flight would impact the overall control of the drone and the image quality of the images being taken.
4. For socio-cultural concerns, public privacy is the highest criteria
5. For regulatory, following all Canadian laws is the highest concern
6. For environmental, keeping the drone environmentally friendly, specifically the battery, is the most important factor.

- **What are the most significant disagreements?** If there is a disagreement among the team members on a suggestion(s), list those points here. What are the reasons behind the disagreements?

The most significant disagreement within the team is setting the priority upon the decision of flight speed. Some of our group member think that the flight speed would be essential to the efficiency of execution of the project. As the member propose that, the higher the speed of drones, the faster the systemic project goes. However, other members of teams have counter argument. They consider that the flight speed would be determined to be less important because without a stable image, a high-quality image is not possible, and without a high battery life, the speed of the drone is not important. The high speed could also lead to worse overall control of the drone and worse image quality because the drone moves more rapidly. Looking on the bright side, our group have already determined the agreed and prioritized three aspects, which would make this disagreement be not ineffective but interesting communications of thoughts.

In the past session, you discussed several design choices and possibly several different designs for your final product. This week we expect you will be moving towards final decision / selections.

To do so, you are required to organize your design decisions into a systematic/quantifiable approach using design matrix. Using outcomes of your asynchronous activity and the previous task create a design matrix consisting of three different criteria and 2-3 different design configurations / choices.

For example, using Tables describing drones and machine learning algorithms from Week 5 you could create a design matrix consisting of several drone/algorithm combinations and select optimal choice using criteria you selected as a team in the previous task.

You may need to come back and modify your weights/grades and/or configurations/choices before you finalize your decision. Furthermore, in the following week you will be provided with an additional model including environmental noise that will enable you to refine your design choices possibly taking into account weather conditions in the area you selected for monitoring.

Criteria	Weights	Only Performance		Performance & Socio-Cultural		All PERSEID Layers	
		Score	Total	Score	Total	Score	Total
Maximize Performance	5	5	25	4	20	3	15
Good Battery Life	3	5	15	4	12	3	9
Flight Control, Stability and Path	4	5	20	3	12	2	8
Public Privacy	4	1	4	5	20	5	20
Follow Laws	5	1	5	2	10	5	25
Environmentally Friendly	3	1	3	2	6	5	15
Grade			**72**		**80**		**92**

The drone that came out to be the most efficient with our criteria was the drone that was analyzed through all PERSEID layers.

Submission Instructions

Upload a *.**PDF** copy of the Wk-9 - Synchronous Design Studio 9 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 9** by March 20^{th}

- Use the following naming convention: **Tut#_Team#_SynchDS9.pdf**

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2 McMaster University

Week 10: Synchronous Design Studio

Source Water Monitoring Project

PERSEID Method: Validation and Testing

Overview

This week you will be performing the final steps of your design. Specifically, you will be validating/testing your design choices with respect to performance metrics discussed in previous design studios. In your asynchronous activity you were asked to perform a preliminary qualitative/quantitative error analysis. In this synchronous activity you are expected to share your findings within your group and finalize certain design choices based on your previous selections and desired performance thus validating your design with respect to the performance it offers.

Desired Performance:

Recall that we use false positive (FP) to refer to scenario in which your monitoring system decides there is an algal bloom while in reality there is no bloom in the lake. Similarly, false negative (FN) refers to the scenario in which your monitoring system decides there is no algal bloom in the lake, while in reality there is an algal bloom. Selecting the FP and FN rates is a rather complicated process involving both expert opinion and a cost analysis. In this exercise you are asked to make certain decisions based on your group consensus. You will not be graded on the decision that your group makes; rather you will be graded on the discussion and justification of your group's decision.

Please be aware of the following: a) the FP rate means that FP% of times you will be sending someone to obtain a water sample from the lake (potentially remote depending on your site choice), b) the FN rate means that FN% of times you will allow an algal bloom to grow without managing lake usage or downstream treatment strategies until you send your areal monitoring system back to that area again, and c) 0% error, while desirable, is not technically feasible.

ENGINEER 2PX3: INTEGRATED ENGINEERING DESIGN PROJECT 2

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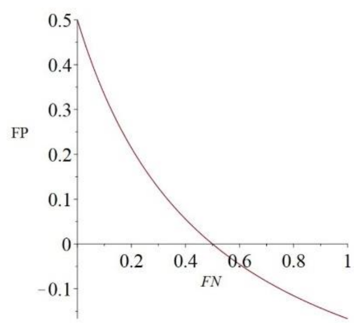
1. Error Analysis: Discuss as a group what you believe reasonable to be choices for FP and FN rates. Include in your discussion the role (if any) that your location choice plays in these choices. In real world designs you often need to balance these decisions because they cannot both be arbitrarily small. Assume that FP and FN are empirically modeled using following relationship:

$$FP = \frac{1 - 2 * FN}{4 * FN + 2}$$

where FP and FN represent false positives and false negative rates on a scale of 0-1 (i.e., percentage values divided by 100%). Reconsider your group's choices for FP and FN and decide whether they would remain the same under the above constraint.

From the above equation, we plotted the following relationship between PF and PN.



(Graphed using Maple Software)

The graph above shows that smaller FN rates lead to exponentially larger FP rates.

Our primary goal is to minimize the FN rates because they pose a health risk to the surrounding life (plants and animals) and lake residents. We chose to prioritize FN over FP rates because the only downsides of a high False Positive rate is cost and time, which are not major considerations in the project, and therefore our decisions are justified.

From this graph we see that a 1% FN will lead to a 48% FP, a 2% FN will lead to a 46% FP, while a 3% FN will lead to a 44% FP, from these we have chosen a maximum False-Negative rate of 1%, this will lead to a maximum False-Positive rate of 48%.

2

2. Model Selection: Reconsider the machine learning algorithms and drones from Week 5 of your design studio, and discuss whether which of these models are more, or less, appropriate considering the choices you made in this week's design studio. Please explain/justify your choices.

Looking at the machine learning algorithms, the most appropriate algorithm is the Convolutional NN, with a FP rate of 4% and a FN rate of 1%. The CNN is the best choice because false negatives are much more dangerous than false positives, and should be minimized, so the CNN has the lowest false negative rate.

Because economics are not factored into choices within the project, using multiple NN to help decrease false detections is possible with no downside. The second best NN that would be used alongside the CNN is the Deep NN, with a FP rate of 1%, and a FN rate of 3%. The DNN has a low false positive rate, which helps make up the higher rate that is given by the CNN.

If either of the two NN detect a positive, the algorithm as a whole would produce a positive result, and the lake should be investigated.

3. In this week's asynchronous activity you were asked to consider how combining different decisions using different algorithms can potentially improve the performance of your system. To assist you in your reasoning, consider the following example in which we combine two algorithms. Let's assume that the FP and FN rates of two algorithms are FP1, FN1, FP2, and FN2, respectively. Let us assume that our decision-making scenario specifies that an algal bloom is detect only if both algorithms say that a bloom is present. The FP rate for this scenario is FP1*FP2, which is smaller than either of two individual algorithms because both of them would need to make an error. However, the probability of FN under this scenario is given by:

$$FN = 1 - (1 - FN1)(1 - FN2)$$

Is this false negative larger or smaller than the false negative values based on the individual algorithms? Calculate these values for several (FP, FN) pairs using the constraint from Scenario 1. Do you believe combining the decisions using this scenario is a good choice? Justify your reasoning.

FN_1	1%	2%	3%	3%	3%
FN_2	1%	1%	1%	2%	3%
FN	1.99%	2.98%	3.97%	4.94%	5.91%

If both of the NN require a positive detection, combining multiple algorithms would increase the false negative rates, which is not ideal. False negatives are when the algae in a lake is not detected and gone unnoticed, which is a big concern. When both of the algorithms must agree on a positive detection, this makes any disagreement result in a negative outcome, which leads to higher false negatives.

A better approach to reduce the rates of false negatives using multiple algorithms would be to output a positive result if either of the algorithms detect algae. This then would make the FN rates equal to $FN_1 \cdot FN_2$, but increase the false positive rates to $FP = 1 - (1 - FP_1)(1 - FP_2)$. Because false negatives are prioritized more than false positives, and the economics of manually checking the lake are not accounted for, the increase of false positive rates is outweighed by the benefits.

4

4. Based on today's work, describe how you would test the performance of your proposed source water monitoring system. Note that the performance of a system calculated based on a lab/simulation environment is usually different from the actual performance obtained on site. You are expected to clearly state your proposed experiment, including location, sampling times (what part of year, how many flights, environmental conditions, etc.), in situ sampling of the water, as well as machine learning algorithm (or algorithms if you decide that combination of multiple algorithms is viable option).

Experiment Conditions:

- Lake St. Clair, open location away from large populations
- Weather: ideal, sunny / partially cloudy, low winds, etc.
- Time of year: Late spring, summer, or early fall. These times are when algal blooms are present
- Several flights along same path to get a larger sample size, average results
- Minimal obstacles in the air, such as birds

Measurement of Performance:

- Battery Life
- Flight path optimization
- False Positive and False Negative rates

Methods of testing:

- How many flights can be completed in one full battery life.
- Testing how well flightpaths optimize for battery-life and flight times.
- Test out how well the drone follows the given flight path and makes dynamic adjustments if needed.
- Testing our chosen combination of CNN and DNN algorithms to get experimental false positive and false negative rates, comparing them to the ideal statistics and the true conditions of the water.

Submission Instructions

Upload a *.**PDF** copy of the Wk-10 - Synchronous Design Studio 10 Worksheet to the Avenue Dropbox titled **Synchronous Design Studio Week 10** by March 27th

- Use the following naming convention: **Tut#_Team#_SynchDS10.pdf**