SYSC 4907 – ENGINEERING PROJECT

Wind Turbine Ground Vibration Simulator and Sensor

Team Members

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The purpose of the proposal is to introduce the project that you will construct over the course of this academic year. The proposal should be written in such a way that it can be understood by a person not familiar with the project (e.g., the project coordinator.). At the most basic level, every project is trying to build an engineering solution to a problem. This proposal should contain a **brief background**, **describe the problem**, your **preliminary solution**, your **plan to implement the solution**, the **task of each team member and major milestones**, and the **justification of the suitability of the task for the undergraduate degree of each team member**. As with all other deliverables, the proposal must use formal and professional language. Refer to the Proposal section for more details and the Deadlines section for the due date.

1 Introduction

Carleton University's Davy Lab is a conservation research group that works to better understand how environmental changes affect local threatened species of bats, amphibians, and reptiles. One such project involves investigating the effects of seismic vibrations from nearby wind turbine operations on the development of turtle eggs. Further, nearby highways can also generate ground vibrations that may have similar effects that must be studied.

Meia Copeland, Shawaiz Khan, Talal Jaber, Marwan Zeyada and Ranishka Fernando are working to create a device that can simulate the ground vibrations around wind turbines, so that the lab can study these effects in a laboratory setting.

1.1 Background

In the past decade, wind power has been the fastest growing source of new energy in Canada [1]. As the country moves towards its climate goal of increasing the share of zero-emitting energy sources to 90% by 2030, wind power will be instrumental to success. While an extremely useful tool in emission-free power generation, there are a variety of potentially negative effects on wildlife. The most thoroughly studied are the impacts on flying animals, such as bird and bats. Mortality from collision with the turbine rotors, as well as general avoidance of areas around turbines has been described [2]. However, wind energy's impacts on ground-dwelling animals are less known.

On-shore wind farms have been shown to produce low-frequency ground vibrations for many kilometers surrounding the turbines [3]. Some studies have investigated the impacts these vibrations have on the stress levels and behavior of ground-dwelling animals. While some terrestrial animals have shown increased levels of stress-hormones around wind turbines [4], the behavior of most terrestrial animals has not been shown to be significantly affected [5]. Most studies so far have focused on terrestrial mammals. The effects on egg development of reptiles and amphibians have not been examined.

The ground vibrations from wind turbines are predominantly caused by interactions between the wind and the turbine system as a whole, rather than just the spinning of the blades [6]. These frequencies typically range between 0.1 – 100 Hz [3]. To simulate these extremely low frequencies in a lab setting, a shake-table will be needed. The turtle eggs may be placed in an incubator, which in turn is attached to the top of the shake-table. Devices capable of such low frequencies exist, such as the Low Frequency Portable Shaker Table by the Modal Shop, which is capable of frequencies as low as 0.7Hz. However, the price on such a device is prohibitive to the Davy lab. The device is also not rated for continuous use throughout the incubation period of turtle eggs.

1.2 Motivation

As wind power becomes commonplace around Canada and the world, it is important to determine the effects wind turbines have on native species that may live or nest nearby. The

Davy Lab would like to investigate these effects on the development of turtle eggs, particularly the ground vibrations caused by wind turbine use.

Our goal is to create a device that will allow the Davy Lab to simulate these ground vibrations in a laboratory environment, while also tracking environmental variables such as temperature and humidity.

1.3 Project Objective

This device will simulate frequencies between 2 – 10 Hz, with amplitudes around 10^{-4} mm/s and 10^{-6} mm/s to simulate vibrations directly around the turbine, and up to 2.5 km away. A table-top will be used to hold multiple incubation tubs. Vibrations on each tub will be measured independently. The device will be able to create vibrations for up to 90 days, or as long as the incubation period of the eggs.

Specific Goals

LOW FREQUENCY MOTORS – Multiples of the same motor will be used, with each motor taking a turn as to prevent burn-out over the 90-day experiment period. Motors must be capable of shaking the table-top at 2-10 Hz or be connected to a system that will reduce their frequency to this level.

MOTOR CONTROL SYSTEM – System will be developed to allow for variable frequencies and amplitudes, which can be selected through a touchscreen interface. The system will alternate motors being used and control the speed-up and slow-down of motors.

LOW FREQUENCY VIBRATION DETECTION – Accelerometers will be placed on each incubation tub to measure the applied vibration frequency and amplitude.

TOUCH SCREEN CONTROL – A touch screen user interface will allow the lab members to start and stop the experiment, set the frequency and amplitude variables, export data to an emailed spreadsheet, and monitor the environmental and vibration variables during the experiment.

ENVIRONMENTAL MONITORING – Temperature and humidity sensors will be monitoring the lab environment at the same frequency of the vibration sensors.

2 Research

2.1 Vibrations to be simulated

Several papers on the ground vibrations around wind turbines were examined to determine the target frequencies and amplitudes for the simulation device. Much of this research has been conducted to examine the interference wind turbine ground vibrations may have on sensitive seismic monitoring systems. Reports have shown that vibrations from wind turbines can interfere with these systems as far as 62 km away when wind speeds are high [3].

Several reports agreed that there are distinct structural bending 'modes' detected around typical 80m tall turbines [3] [7]. These modes correspond to vibrations of 0.32 Hz, 2.56 Hz and 5.88 Hz.

The amplitude of vibrations is also needed to create an accurate simulation of the vibrations around turbines. Botha found that the amplitude of an approximately 5 Hz vibration 90 m from the base of turbine was 10^{-4} mm/s [8]. At 2 km from the base, the vibrations were attenuated to 10^{-6} mm/s.

For this simulator, creating vibrations like those felt close to the base of the turbine will be prioritized. A frequency of 5.8 Hz and amplitude of $^{10-4}$ mm/s will be targeted. If these variables are achieved, reducing the amplitude and frequency will be attempted.

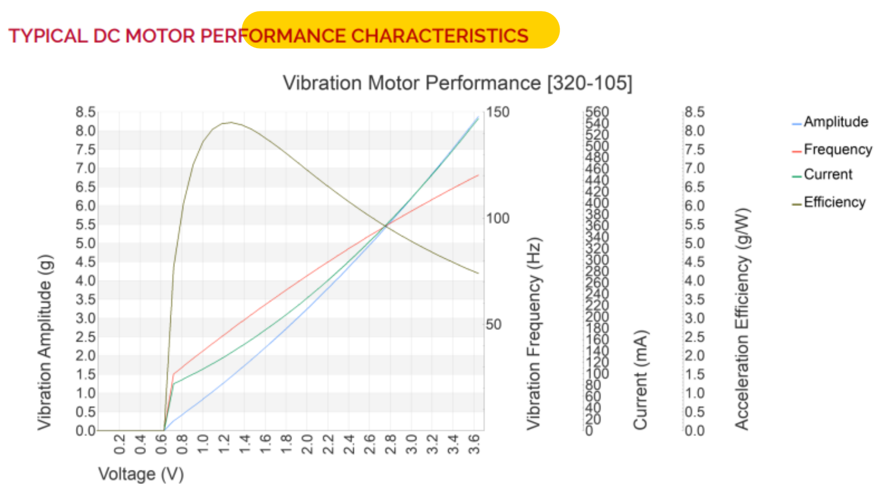
2.2 Methods of simulation

2.2.1 Electrical

One of the first options that were considered is a tactile transducer since it is generally easier to control and more accurate than normal vibrating motors. But one of the main issues is that the transducer will overheat if it ran on such a low frequency for extended periods of time. The coil can also be overloaded electrically which will cause the coils to break[10]. One of the ways we can solve this issue is pulsing a sine wave instead of a continuous input.

2.2.2 Mechanical

The other option the team is looking into is using a simple vibrating motor attached under a tabletop with some insulating pads near the legs for eliminating noise. The types of motors that can be used are brushless 3 phase motor with a PWM controller to control the RPM of the motor since the rpm is directly proportional to the frequency vibration. The issue with small motors is that the vibration frequency stops decreasing at around 30hz with most motors due to there weight and size(figure 2). We are currently looking at stepper motors as an alternative to normal dc motors since they operate on much higher torque and lower speeds which is what we are looking for.



(Figure 2) DC motor frequencies [11]

3 System Design

3.1 Motor Test Plan

….

3.2 System Overview Diagram

Provide a UML deployment diagram showing your proposed solution at a high level. Describe and discuss this figure. Provide a rationale for why you have approached the project using this design/structure.

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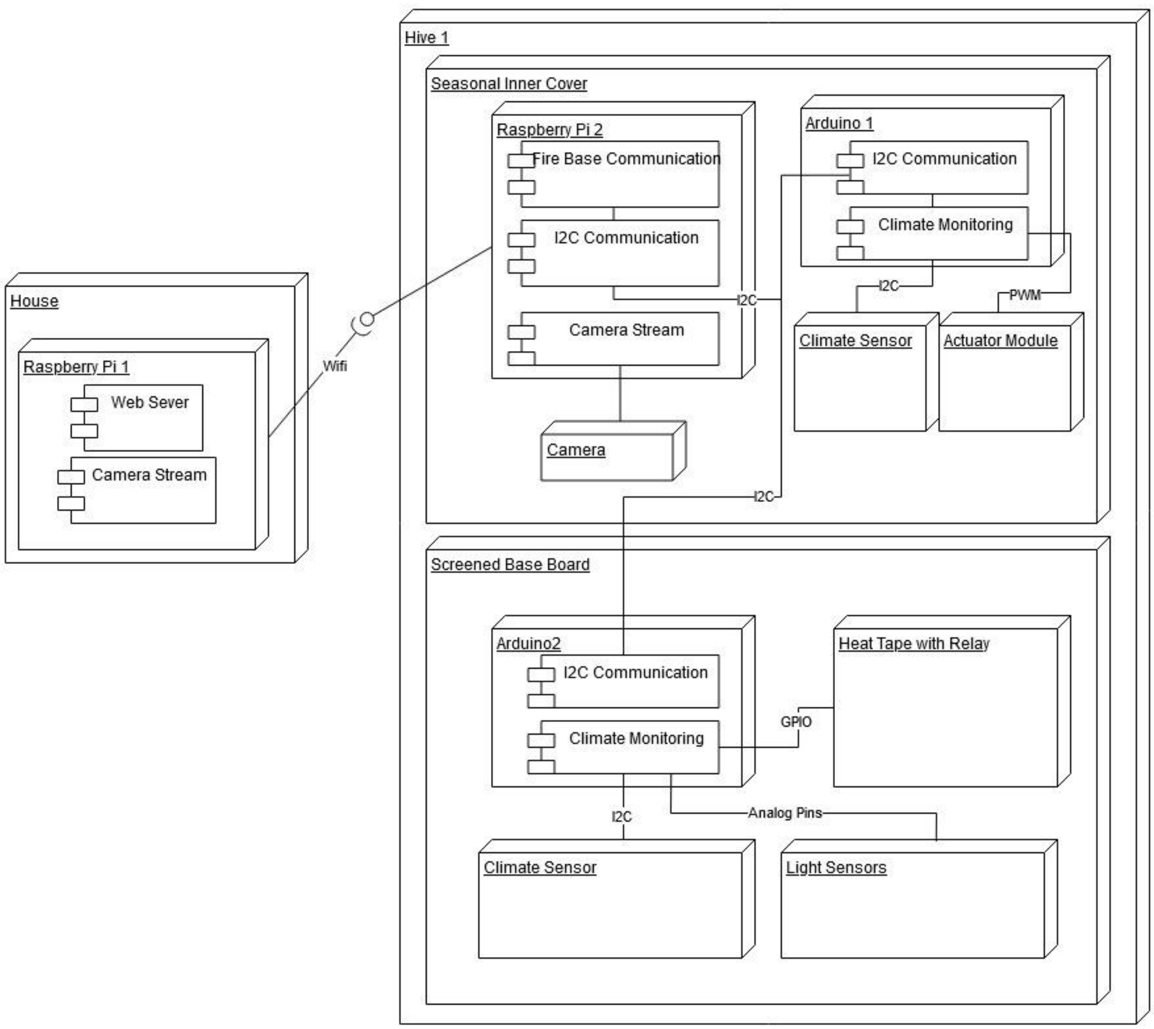

Figure 1:This is just an example

Aim for modularity. Each component or module should be independently testable and (theoretically) could be reused in another project. Requires clear definitions of "interface" for each module: What are is inputs? What function does it complete? What are its outputs? This approach allows you to develop and test each component independently.

Aim for scalability. If you are designing a home security system, the number of doors and windows should be flexible. If you are designing a greenhouse automation system, the number of plants or racks should be flexible. If you are designing a tennis court occupancy tracking system, each city can own many facilities and each facility can have many tennis courts. One sign of good scalability is that each "object" has an ID (plant_ID, court_ID, house_ID, facility_ID, door_ID, etc.)

3.2.1 Communication Protocols

Your deployment diagram should indicate how you will communicate between each node **and also** between your computers (RPi) and any hardware devices. Try to be specific. For example:

- What type of GPIO/serial protocol will be used for hardware?
- What type of IoT communication tool will be used to communicate between nodes? How many channels or databases will you require?

3.3 Component Details

For each of the major components or nodes in your system overview diagram, describe and discuss how it will be designed. Components may include database server, central server, sensor system, GUI, etc. **Discussion will likely include** circuit diagrams, GUI wireframe mock-ups or sketches, database schemas, etc., but your report is more than a collection of diagrams; be sure to discuss each figure.

Some of this detailed information will be clarified in the "Detailed Design Document", but try to reach ahead…

3.3.1 Component 1

The first component in the proposed system is the …

3.3.2 Component 2

…

3.4 Use Cases

3.4.1 Use Case 1 – Begin New Experiment

Intent: Turning on the system and setting up a new experiment.

Primary Actor: Biologist/Student

Precondition: The system is connected to power.

Postcondition: The user successfully turned on the system and set up a new experiment. The parts operate at the intended settings.

Failed Postcondition: Either one of the motor, accelerometer, temperature sensor, humidity sensor fails to operate.

Basic Flow:

- Press the manual On/Off button.
- Navigate through the touch screen interface.

    1. Press “New experiment”.
    2. Enter an experiment name, desired frequency, desired amplitude in the given space and press “Next”.
    3. Review the details entered; Enter your email in the given space and press “Start”.

Alternative Flow:

1. Repeat step 3 if more emails need to be added.

3.4.2 Use Case 2 – Change temperature/humidity units.

Intent: Changing the temperature/humidity unit.

Primary Actor: Biologist/Student

Precondition: The system is connected to power, ON, and NO experiment has been setup.

Postcondition: The user successfully changed the unit to the desired option.

Failed Postcondition: The system fails to record data in the chosen unit.

Basic Flow:

- Navigate through the touch screen interface.

1. Press “Settings”.
2. Press “Change Units”.
3. Press “Temperature” or “Humidity”.
4. Choose one of the given temperature or humidity units and press “Done”.

3.4.3 Use Case 3 – Change frequency/amplitude.

Intent: Changing the frequency and amplitude of the vibrations by the motor.

Primary Actor: Biologist/Student

Precondition: The system is connected to power, ON, and an experiment has been set up and is running; The UI displays the home screen.

Postcondition: The user successfully changed the frequency/amplitude to the desired setting. The system uses the accelerometer to measure the change and display a confirmation notification.

Failed Postcondition: The accelerometer fails to detect a change or detects readings not intended by the user.

Basic Flow:

- Navigate through the touch screen interface.

1. Press “Settings”.
2. Press “Change Frequency/Amplitude”.
3. Use the slider to choose the desired frequency and enter the desired amplitude in the given space and press “Finish”.

Alternate Flow:

1. Press “Change Frequency/Amplitude” shortcut on the Home Screen.
2. Step 3 from the Basic Flow

4 Work Plan

4.1 Project Team

Describe your team, including strengths/interests for each member.

Meia Copeland is a fourth year Computer Systems Engineering student. Through her 7 co-op placements and internships, she has developed

Shawaiz Khan is a fourth year Computer Systems Engineering student. Working on previous projects during his studies, he acquired knowledge and skills in both hardware and software. Having a bit of experience in dealing with this before, he will mainly be working on setting up the database with SQL, as well as assisting in setting up the accelerometer, temperature and humidity sensors. Interested in learning more and gaining experience with front-end development, he will be assisting with the UI framework as well.

4.1.1 Roles and Tasks

List the major roles/tasks assigned to each group member (use a list or a table). Who will be *primarily responsible* for each component/node in the project? Who will be secondary (testing, etc.) for each?

Briefly discuss why have you assigned the duties in this way.

Also justify the suitability of each person's tasks to their degree!

4.1.2 Teamwork Strategy

Briefly discuss how will you work together effectively as a team. What development standards or workflows will you follow/enforce, what team communication strategy will you use, etc.? (code reviews, pull requests, GitHub issues, train vs. test, etc.)

4.1.3 What we will need to learn

List and briefly describe the various technologies that you will have to learn to accomplish the project.

4.2 Project Milestones

Include a table of major milestones in the project. Each milestone should have a name, a date, and a description (1-3 sentences). Milestones should be concrete and verifiable (i.e., on the date of each milestone, we should be able to verify did you, or did you not, meet each milestone?) Milestones are not simply course deliverables/deadlines. They represent significant technical achievements in your project.

4.3 Schedule of Activities

Include a figure showing a timeline that includes all project milestones and also deliverables/deadlines. Consider adding **tasks** to your timeline, where tasks culminate in milestones and deliverables.

Optional: provide a Gantt chart showing what each team member will be working on in each week of the project.

5 Project Requirements Checklist

For each requirement on the project checklist (see Project Overview), indicate how you have addressed each requirement. Only 1-2 sentences are expected per requirement. Could be formatted as a table, list, or text.

5.1 Stretch Goals

Add some stretch goals for if there's extra time! Not required.

6 Hardware Required -> Rename to reflect hardware & software?

What components, services, parts, etc. will be required by your group to complete the project? Try to include Digi-Key part numbers (in a table) for any electronic components that you anticipate requesting on the "Component Request Form" before the winter break.

7 References

[1] "By The Numbers," Canadian Renewable Energy Association, January 2022. [Online]. Available: https://renewablesassociation.ca/by-the-numbers/. [Accessed 18 September 2022].

[2] C. B. Thaxter, G. M. Buchanan, J. Carr, S. H. Butchart, T. Newbold, R. E. Green, J. A. Tobias, W. B. Foden, S. O'Brien and J. W. Pearce-Higgins, "Bird and bat species' global vulnerability to collision mortality at wind farms revealed through a trait-based assessment," *Proceedings of the Royal Society Biological Sciences,* vol. 284, no. 1862, 2017.

[3] W. N. Edwards, "Analysis of measured wind turbine seismic noise generated from the Summerside Wind Farm, Prince Edward Island," Natural Resources Canada, Prince Edward Island, 2015.

[4] R. Łopucki, D. Klich, A. Ścibior, D. Gołębiowska and K. Perzanowski, "Living in habitats affected by wind turbines may result in an increase in corticosterone levels in ground dwelling animals," *Ecological Indicators,* vol. 84, pp. 165-171, 2018.

[5] R. Łopucki and I. Mróz, "An assessment of non-volant terrestrial vertebrates response to wind farms—a study of small mammals," *Environmental Monitoring and Assessment,* vol. 188, no. 122, 2016.

[6] P. He, J. González-Hurtado, T. Newson, H. Hong, M. Postmann and S. Molnar, "Field monitoring of the ground vibrations adjacent to an," *Canadian Geotechnical Journal,* vol. 58, no. 4, pp. 595-602, 2019.

[7] D.-P. Nguyen, K. Hansen and B. Zajamsek, "Human perception of wind farm vibration," *Journal of Low Frequency Noise, Vibration and Active Control,* vol. 39, no. 1, pp. 17-27, 2020.

[8] P. Botha, "Ground Vibration, Infrasound and Low Frequency Noise Measurements from a Modern Wind Turbine," *Acta Acustica united with Acustica,* vol. 99, no. 4, pp. 537-544, 2013.

[9] S. Borowski, "Ground vibrations caused by wind power plant work as environmental pollution - case study," *MATEC Web of Conferences,* vol. 302, no. 01002, 2019.

[10] EarthquakeSound.eu. (n.d.). Tactile FAQ - earthquakesound.eu. Retrieved October 1, 2022, from http://www.earthquakesound.eu/info/faq/tactile-faq.aspx

[11] *DC motors and Mechanisms*. Precision Microdrives. (2022, May 27). Retrieved October 1, 2022, from https://www.precisionmicrodrives.com/

Appendices

You may wish to include appendices. For example, detailed circuit diagrams, detailed wireframes, data sheets for special components, etc.