UNIVERSITEIT TWENTE.

# SMART ENVIRONMENTS PROJECT

# DOCUMENTATION REPORT

<Group 16 B.A.T.S.S.>


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## Chapter 0: Introduction

This research paper aims to explore a potential solution for the Dutch bat population decline. This solution is proposed by team B.A.T.S.S., consisting of Bart van Dorst, Samuel Overtoom, Anthony Mammoliti, Madeleine Leertouwer, Niels Brouwer, Phebe Biney, Robin Geilings and Sahan Berndt.

The problem being tackled is the bat decline in the Netherlands. Out of the 7 bat species inhabiting the Netherlands, over the last decade 3 species have seen a significant decrease in population. [23] This is a problem since bats play a significant part in maintaining the ecosystem and the natural order of creatures, such as by controlling insects and pollinating flowers.[24] As well as carrying pollen and seeds, bats are known to consume large quantities of insects. Because it regulates habitat, this is crucial for the ecosystem. Collisions with wind turbines are one specific cause of bat deaths.

The solution proposed is to create a system designed to ward off bats from wind turbines, as wind turbines are a tremendous cause for bat population decline.[31] The number of dead bats found by Fiona Mathews et al. during their survey ranged from 0 to 5.25 per turbine and from 0-77 per site. [32] Due to the changing air pressure, bats that approach wind turbines too closely might also suffer from barotrauma. In the system we've created, we detect the frequency of bats using their ultrasonic signals, and then we scare them away by sending ultrasonic waves back their way. Thereby, hopefully, slowing the decline of bats.

## Chapter 1: Literature Review

‘Monitoring common and scarce breeding birds in the Netherlands: applying a post-hoc stratification and weighting procedure to obtain less biased population trends’ [1]
This article is about the reworking of the way scarce breeding birds are currently monitored in the Netherlands. Currently the system used assumes that the measurements in every plot are valid for adjacent plots or other averages. This article proposes a way of measurement to undo this bias.

‘The effect of roads and traffic on hedgehog (Erinaceus europaeus) populations’ [2]
This article is about monitoring the effect of traffic on the hedgehog population in the Netherlands. According to the article the existence of roads/traffic can lead to a decline in the hedgehog population in an area by up to 30%.

Effects of habitat fragmentation on the red squirrel, Sciurus vulgaris L. [3]
This article is about the impact of habitat fragmentation on red squirrels. The research shows that the squirrels were less likely to inhabit smaller wood plots which implies that fragmentation of these woodplots would lead to less squirrels.

‘A Smart Camera Trap for Detection of Endotherms and Ectotherms’ [4]
Current camera traps are only able to capture pictures of Endothermic animals. This article describes the design and build process of a smart camera trap that uses artificial intelligence to also be able to capture pictures of Ectothermic animals, such as reptiles. Field trials demonstrate that this system successfully recorded a high number of animals.

‘Dutch hedgehogs Erinaceus europaeus are nowadays mainly found in urban areas, possibly due to the negative Effects of badgers Meles meles’ [5]
This article is about the question: is the growth of the badger population in the Netherlands the reason that the hedgehog population is declining and are those badgers the reason that hedgehogs are attracted to the city? The result of the study was that there was not a clear answer, because the badger did negatively affect the hedgehog population but not to the decree that the researchers were looking for. It was suspected that hedgehogs seek refuge in cities to flee from the badgers but it is not certain.

‘Occupancy dynamics of wild rabbits (Oryctolagus cuniculus) in the coastal dunes of the Netherlands with imperfect detection’ [6]
This article addresses the local extinction of the wild rabbit in the coastal dunes of the Netherlands. Their reasons for this extinction is believed to be due to an aggressive disease. Over the years the rabbits start to reappear slowly due to the quality of the woodlands being poor. These researchers noticed that the detection of rabbits increased when the weather was rainy, cloudy, and windy. Another instance where the detection of rabbits increased was when a new moon approaches.

‘Projected changes in wildlife habitats in Arctic natural areas of northwest Alaska’ [7]

This article covers the effects of changes in wildlife in northwest Alaska. The article aims to predict and estimate the changes in species and habitats. Where factors for the decline in wildlife are discussed, temperature being the most prominent.

‘Animal Recognition and Identification with Deep Convolutional Neural Networks for Automated Wildlife Monitoring.’ [8]
This article regards monitoring animals using trail cameras and a program. The program was able to detect animals in photos that were taken by the trail cameras and proceed to analyze them to try and decipher what species the animal was. The pictures used for this article were done in South-central Victoria, Australia. The results of this expariment are 96.6% accuracy for detecting animals in the pictures and 90.4% accuracy for working out what species they were.

This article's main scope was to make it seem feasible to have fully automated wildlife observation. The reason to want this is so that it would be much faster for us to understand what is happening to the wildlife. The reason we want to understand wildlife is so we understand their habits and behavior, therefore we can check if it has changed due to human action.

‘Trans-Canada Highway Wildlife Monitoring and Research’ [9]
This article is about monitoring a wide range of species and their habits. These species often cross the Trans-Canada Highway (TCH) which leads to multiple cases of wildlife-vehicle collisions. Using this research solutions were implemented and the number of wildlife-vehicle collisions has decreased greatly.

‘Monitoring Songbird Population Change with Autumn Mist Netting’ [10]
This article is about the monitoring of the songbird population, in order to prove that the population of birds changes. This demonstrates that the migration of birds with use of mist netting can be used to detect population change.

‘Aquatic insects as bio-indicator of water quality A study on Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India’ [11]
This article discusses the usage of aquatic insects to indicate the quality of the water in the Chakrashila Wildlife Sanctuary. This study revealed more species in the water. Where the influence of environmental variables in the diversity of aquatic insects is discussed.

‘European red squirrel population dynamics driven by squirrelpox at a gray squirrel invasion interface’ [12]
This article regards the decline of native squirrel species due to an infectious disease called squirrelpox, introduced by non-native species. This disease has a negative effect on the native species (red squirrel), as seen in the decline of red squirrels, while it has not a lot of impact on gray squirrels.

‘Fast and accurate annotation of acoustic signals with deep neural networks.’ [13]
The paper introduces the use of a new method (DAS) to annotate acoustic signals of lots of animal species. They demonstrate the working of the method by using it on acoustic signals

from insects, birds, and mammals.

A comparative assessment of track plates to quantify fine scale variations in the relative abundance of Norway rats in urban slums’ [14]
Current methods of accurately researching the rat population aren’t effective or are too expensive. The method of using track plates does work well on a bigger scale, but can not be used to survey local areas. The new track plate method they have developed is designed to also research rat abundance locally. In this article they research the effectiveness and accuracy of the new tracking plate method.

‘Looking for new emperor penguin colonies? Filling the gaps’ [15]
The use of a new method of looking for and monitoring penguin colonies has led to the discovery of many new (smaller) penguin colonies. By using satellite imagery and remote sensing the monitoring of colonies will be more effective and proper research can be conducted to better understand the effects of the warming of the planet on the habitat and population of these penguins.This method is what the paper analyses.

‘Beavers’ [16]
Beavers (Castor canadensis), once one of the most extensively dispersed mammals in North America, have seen a significant drop in population. Populations of beaver have been destroyed by uncontrolled trapping for pelts. Beavers that construct dams that flood agricultural or other privately owned fields have also been killed by landowners.
In reality, beavers cause far more good than bad. Since they can change the environment to suit their purposes, they are also referred to as environmental engineers. This allows them to create valuable wetlands and habitat for a variety of plants and animals. Ecologists have classified these wetland habitats as the most advantageous ecosystem on the planet because they mitigate both regional floods and droughts.
The ecology and the beaver species have suffered because of the population decline. The number of beavers in North America is thought to be only 10% of what it was prior to European settlement.

‘Using long-term monitoring of red fox populations to assess changes in rodent control practices’ [17]
To exterminate invasive rodents from islands or to manage agricultural pests, anticoagulant rodenticides have been applied over vast regions (thousands of ha). Although systematic removal of invasive rodents from islands using these pesticides saved the extinction of species and restored ecosystems, there have also been reports of substantial consequences of ARs on populations that are not targeted. In New Zealand, for instance, bird numbers were found to be down (20–100%) as a result of these exterminations.

‘Evolution and sustainability of a wildlife monitoring sensor network’ [18]
Evolution and sustainability of a wildlife monitoring sensor network. Sensor networks are maturing more and more and are being used in the monitoring of wildlife a lot. Efforts in testing and deploying sensor networks have been made. These resulted in unmatched sensing capabilities. The system is composed of a wireless sensor network designed to monitor wildlife and environmental conditions in a dense woodland environment. They do this by tracking badgers with collars.

There’s often many things to pay attention to, like making monitoring material that is an appropriate size, often small, is very reliable, and inexpensive.

‘Drones and wildlife monitoring - is it a good idea?’ [19]
Drones get used in wildlife monitoring, but some animals don’t take that well. Yee Von Teo describes her research in wildlife monitoring with drones, and the techniques they use for every different species, like using the sound of drones to scare away elephants from farmland.
Animals tend to distrust the electronics that monitor them, such as drones.
Animals put themselves in dangerous situations, like the kenyan elephant who goes onto farmland.

‘BearCam: automated wildlife monitoring at the arctic circle’ [20]
In order to monitor grizzly bears at the arctic circle, the researchers developed a camera system that would be able to withstand the extreme weather conditions while making use of intelligent motion detection algorithms to use energy most efficiently. Their system includes solar cells for additional power and a heater to regulate the temperature of the system.

‘A wireless sensor network for underground passages: Remote sensing and wildlife monitoring’ [21]
The research focuses on detecting wildlife that passes through a passage using a Wireless Sensor Network. To limit the cost of each node, they opted to do this detection without the use of cameras and instead decided to use sensors that measured distance and weight. To get the most accurate classification of their collected data, they used machine learning to train clustering algorithms that would give them a certainty score of 90% for each detection and classification.

‘Adaptive Ultra Low Power Sensor Network for Animal Tracking’ [22]
The researchers worked on designing a Wireless Sensor Network of nodes that are directly attached to the animals being monitored. This required the nodes to work with a very limited energy budget. Because they focused on monitoring bats, these nodes had to be extremely light weight, further limiting how data could be transmitted and how efficient each node must be with how it uses electricity.

# Chapter 2: Identification of General Problems and Challenges

In this chapter, 9 general problems and challenges are listed, as extracted from the list of publications in chapter 1.

- Monitoring scarce breeding birds: are they in decline or are their populations stable.
- Traffic killing hedgehogs and decreasing their population.
- Squirrel populations are declining because of the decreasing size of the woods they live in.
- There are some species of birds who are difficult to monitor and thus poorly tracked. Non-native species bringing infectious diseases.
- Existing annotation tool methods fail to make complete and precise annotations at low levels, are not flexible or adaptive, meaning they only work for restricted types of signals and they are not fast enough to work though big datasets.
- Current methods to calculate rat abundance are not often reliable and efficient. Also, traps can influence rat behavior and the interpretation of rat abundance.
- Satellite imagery of the freely available Landsat7 imagery, though cost effective, was not able to be used to spot smaller colonies of penguins, thus leaving colonies and parts of Antarctica undiscovered.
- Animals tend to distrust the electronics that monitor them, such as drones.
- Animals put themselves in dangerous situations, like the kenyan elephant who goes onto farmland.

## Chapter 3: Identification of Relevant Problems

In this chapter, we identify 7 problems that we find relevant, urgent and interesting that have not yet been addressed effectively in Chapter 2.

- The decline of rabbit populations.

Over the past decade the population size of the European rabbit (Oryctolagus cuniculus) decreased about 30%. This sudden drop has been caused by the spread of infectious diseases and a loss in habitat. While some believe this to be beneficial to farmers, as rabbits can be considered as pests, studies show that their decline of population size is a direct threat to endangered wild cats and other bird species.

- The decline of bat populations.

Bats play a critical role in many ecosystems around the world. They help control insect populations, pollinate plants, and disperse seeds. In some cases, bats are the primary pollinators for certain species of plants, and their absence can have a negative impact on the plants and other animals that rely on them. Bats are also important in terms of controlling insect populations. Many species of bats eat large numbers of insects, including pests that can damage crops and spread disease. By controlling these insect populations, bats help protect crops and prevent the spread of diseases. Additionally, bats play a key role in seed dispersal, which helps to maintain the health and diversity of plant communities.

- The disturbance of owl habitats and nests.

With loss of habitat comes a loss of owls. Owls are a key part of the ecosystem. They get rid of pests, thus helping maintain a natural order of animals. A main disturbance in owl habitats is the use of rodenticides by man around owl nests. Rodents are an essential food source for owls, when it is lacking there will very likely be a decline in owls.
In the Netherlands there are about eight species of owls. Four out of those eight species are on a so-called ‘red list’ for birds, which is a list specifically designed for the Netherlands, that contains all the extinct, critically endangered and vulnerable species of birds. Meaning that those four species are in even more need of protection to sustain its survival here.

- The decline of European hamster species.

The IUCN Red List now classifies the European Hamster (Cricetus cricetus), which was historically widely distributed throughout Europe and Russia, as Critically Endangered due to dramatic population decreases that have occurred . According to research, decreased reproductive rates are primarily responsible for the population decrease. In contrast to the majority of the 20th century, when female hamsters gave birth to over 20 pups annually on average, it has been discovered that today's females only have 5 to 6 pups every year. Although the causes of the lower reproduction rates are not entirely known, researchers are looking into the increase of monoculture crops, industrial development, global warming, and light pollution as potential culprits.
As a result, the European hamster is no longer found in more than 75% of its original habitat in Eastern Europe, at least a third of its range in Germany, and three-quarters of its original habitat in the French area of Alsace. Within the next 30 years, the species is predicted to become extinct if nothing is changed.

- Bird habitats are taken away by the building of a city.

As more and more cities are being constructed/expanded it causes numerous problems for birds and their habitats. This destruction of habitat means that these birds need to find other places to live which most of the time are not suitable for them, causing them to die. Habitat loss does not only affect the birds that live there permanently but also birds that migrate to these locations that are no longer suitable for them, thus bringing thousands of birds closer to extinction. Often birds rely on their surroundings for food, primarily relying on trees for their nutrients. Keeping this in mind it is clear that removing these trees causes problems. Along with sustenance trees also provide birds with cover from predators. [26]

- The building of roads restricts safe passage for small animals to cross the roads (frogs, mice).

While the building of roads leads to an increase in roadkill, a more pressing effect is road avoidance by animals due to traffic noise.[27] It creates an even more visible separation in the population of animals, which in turn causes demographic problems, to which the roadkill undeniably adds. The amount of roadkill evidently attracts predators, thus making it more dangerous for small animals to even get close to the roads, which is seemingly why most small animals tend to avoid roads, or at least attempt to.[28] This would mean that they are unable to get to the other side of the road, with perhaps different vegetation, thus limiting them to live on one side of the road.[29]

## Chapter 4: Problem Selection and Motivation

We decided to focus on the problem of declining bat population sizes in the Netherlands. According to the IUCN Red list, from the 7 existing bat species in the Netherlands, at least three species-groups have seen a significant decrease in their population sizes over the last decade. [23] Bats play a vital role in our ecosystems, as they limit the growth of insect populations and are a carrier of pollen. [24] A decline of their populations would lead to a significant rise of insects which in turn can lead to an outbreak of insect [pests]. Because of this and due to the role they play in pollination, bats play an important role in ensuring our ecosystems and our agricultural food production systems stay healthy. This is why we think it’s an important problem to tackle. [25]

## Chapter 5: Potential Solutions

In accordance with the problem declared in chapter 4, the following potential solutions are explored, detailing their inner workings:

**Automatic bat feeder**

One of the main dangers to bats, according to nora(citation?), is related to their food and feeding grounds. Some feed mostly on the ground or in the air, far from trees, while others grab insects from bark and vegetation. Others catch insects emerging from water. There must be a considerable impact on survival and reproduction due to the decline in insect abundance brought on by water pollution, altered agricultural practices, and insecticides. This poses a threat to the bat population, particularly in view of the continuously expanding use of pesticides in the agricultural sector. Our recommendation is to install automatic feeders to feed the bats that are unable to locate their own food supply in order to address this issue. To make sure rodents don't feast off of the food that is meant for bats, the feeder will be encased and only accessible by a door that opens when it detects either the acoustic signal of a bat or the infrared camera recognizes the approaching animal is a bat. [30]

Required materials:

- Ultrasonic sensors (such as HC-SR04 or MaxSonar sensors)
- Breadboard and jumper wires for connecting the sensors and camera to the Arduino board
- Computer or other device for running the program, collecting and processing data and make decisions
- Arduino software for writing and uploading the program to the Arduino board
- Arduino Uno board
- Servo to open the door to the feeder
- Casing that hides the internals and that allows space for the feeding tray and opening mechanism.
- Infrared camera
- A bats preferred food

**Wind turbines with bat proximity sensors**

Since the early 2000s, there has been data from the US, Europe, and the UK showing that bats have run into wind turbines. Indirect effects of wind farms include habitat loss (roosts, commuter routes, and feeding regions) and fragmentation. Direct effects of wind farms include collision and barotrauma (injury to tissues from air pressure changes surrounding turbines). [31]

A study was done from 2010 to 2016 to collect information on the number of bats killed by wind turbines. They discovered that, during the survey period, the estimated casualty rates in their area, which account for predator removals and the effectiveness of the searches, ranged from 0 to 5.25 bats per turbine and from 0-77 bats per site.

Disabling wind turbines at night would be one solution, but since humans rely on the electricity they produce, this is not a very practical option. Making the wind turbines emit a cinnamon spray into the air, or provide adequate lighting for the spinning components would be another option as bats detest both light and the scent of cinnamon. Making a windmill smell like cinnamon is an unrealistic solution, since windmills are incredibly tall. The idea of the lights seems more realistic. This would be done with lights that shine on the wind turbine's blades, which would become brighter when the ultrasonic signals produced by a bat would be detected. The blades themselves could be made to glow, although doing so will not be beneficial for people as the light would be too intense and cause blindness. Another solution would be sending out ultrasonic sound waves back at the bats to scare them away. No matter which solution out of this would be picked, the used sensor should be at the middle of the rotor, and should be wind and waterproof. [32]

Required materials:

- Ultrasonic sensors (such as HC-SR04 or MaxSonar sensors)
- Ultrasonic transmitter
- Breadboard and jumper wires for connecting the sensors and camera to the Arduino board
- Computer or other device for running the program, collecting and processing data and making decisions
- Arduino software for writing and uploading the program to the Arduino board
- Arduino Uno board
- Servo to move the ultrasonic sound producer in the direction of the bat.
- Casing that protects the internals

**Autonomous bat monitoring system**

The following hardware and software elements will be required to create a smart environment that could both monitor and count bat populations using frequency:

- Arduino Uno board
- Ultrasonic sensors (such as HC-SR04 or MaxSonar sensors)
- Breadboard and jumper wires for connecting the sensors to the Arduino board
- Computer or other device for running the program and collecting data
- Arduino software for writing and uploading the program to the Arduino board
- Some sort of camera that preferably can be used at night as well.

Once all the necessary components have been gathered, a program that can control the sensors and gather information on the bat calls must be written. In order to interact with the sensors and gather information about the frequency of the bat calls, this program would need to use the Arduino software. For the program to recognize and distinguish between the calls of various species of bats, it would also need to apply established criteria or algorithms. A series of if-then statements, for instance, may be used by the program to compare the detected bat calls' frequency to benchmarks for various species and categorize the calls accordingly. A way to make this system a smart environment would be to use multiple sensors that could pick up the ultrasound the bats produce to then triangulate their position, pointing a camera connected to the device to take a picture of the location calculated and making sure the data collected gets sent after it has been gathered.

The program would also need to offer real-time statistics on the motions and behaviors of the detected bats as well as maintain track of the number of individual bats. A simple counter variable that is increased each time a new bat call is detected might be used to accomplish this, along with a data structure (such an array or linked list) to record details about the individual bats (such as their species and the time and location of their calls).

The system must be tested to make sure it is operating properly and accurately identifying and tracking the bat populations after the application has been created and the hardware has been configured. This could entail gathering information in the field or in a controlled setting, then examining the data to see whether the system is correctly identifying and tracking certain bats. To increase the system's accuracy and performance, changes may need to be made to the hardware or program.

Once the system is in working order, it may be put to use in the field to gather information about bat populations' movements and behaviors. Researchers and conservationists may use this knowledge to learn more about and better safeguard these animals. Researchers might also access the data using a web-based interface and save it on a computer or server, giving them the ability to see and analyze it immediately or at a later time.

**Smart bat home**

The myotis dasycneme bat's preferred living conditions include favoring a constrained diurnal range (little change of temperature during the day), hunting for surface-living insects in stagnant areas of water and hibernating by relocating to caverns and mountains. [33] [34]

The goal of the smart bat home is to give bats a nest that can self-regulate so that the conditions are exactly in line with the bats' desired living conditions, as discussed earlier. Making it simpler for wild bats to locate a place to dwell and breed will increase the overall bat population. To avoid making bats reliant on the smart nest for survival, the smart bat home should not feed bats. If there is adequate time, the smart bat home should also be able to monitor the conditions in which the bats arrive. For instance, if the bats arrive at the smart nest without food, this may indicate that there is not enough food available nearby.

It might be challenging to find bats that could locate and use the smart nest because some bat species hibernate during the winter which happens to be the season this project is taking place. The materials must also be resilient to adverse weather conditions like rain and cold since they will be deployed outside for a long time.

Another problem is that it is possible that an unanticipated species will nest in the smart nest, creating conditions that are ideal for bats. This could result in either an unforeseen gain (rats finding shelter in the nest and boosting their population) or potential danger for that other species.

Required materials:

- Heating/cooling equipment (preferably silent)
- Microcontroller
- Humidifier/dryer

- Sensing equipment to spot if the heating/cooling should turn on (ultrasound sensor or camera)
- Wood for the casing

# Chapter 6: Solution Selection

We decided to create a system that would repel bats near wind turbines in order to protect them from getting struck by their rotors. Researchers in North America estimate that at least 10,000 to 100,000 bats die every year, in the U.S. and Canada alone[35]. While the root cause of why this happens so frequently is still unknown, there are multiple ways to keep bats away from windmills.

We opted in transmitting specific ultrasonic frequencies that are similar to those that bats use for echolocation. As the frequencies our device sends out are louder than the ones created by the bats, it disorients them and ultimately causes them to leave the area. Initially we thought of using strobe lights to scare the bats away, but because it's been proven that this would disrupt their sleep cycle and even cause damage to their eyes, we decided on using ultrasound instead. Since we transmit  frequencies that they use naturally for echolocation, our device wouldn't cause them any harm.

There are four studies that validate the working of the transmitted frequency on bats. Where they used frequencies between 20-100 kHz to deter the bats, all four studies concluded that the fatalities decreased but did not disappear completely [35].

In our solution, we decided to focus on an individual windmill instead of a full sized wind farm due to the financial and time based limitations of our project. Our device would consist of an array of ultrasonic microphones set close to the upper section of the windmill and a set of ultrasonic transmitters. When the system detects ultrasonic frequencies, the device calculates the direction the soundwave is coming from with the help of the network of microphones. Then it activates the ultrasonic transmitters to blast soundwaves toward the direction of the call.

Modules

| Role | Name |
|---|---|
| **Team leading** | Bart |
| **Programming** | Sahan and Robin |
| **Data collection and analysis** | Niels and Bart |
| **Equipment managing** | Anthony and Madeleine |
| **Presentations** | Bart, Anthony and Niels |
| **Validation** | Robin and Sahan |
| **Documentation** | Phebe and Madeleine |

| **Coach** | Samuel |
|---|---|

# Chapter 7: Methodology

**CRITERIA FOR SMART ENVIRONMENTS**

For a solution to qualify as a smart environment, it needs to sense something and react to it. That is exactly what happens with this current solution, a device gets attached to a windmill and picks up frequencies from one side. When the frequency of a bat is heard, the device reacts by determining its general location and sending out a frequency that scares the bats away. Bats emit frequencies between 9kHz and 200kHz [36]. Since the frequency of a windmill has a maximum of 200 Hz [37], this will not interfere with the receivers, and be mistaken for a bat.

**REQUIRED EQUIPMENT**

The equipment required for the device are as follows:

- 2 x HC-SR04 ultrasonic distance sensor, working frequency 40kHz
- 1 x Charmast 23800mAh 20W PD Power Bank USB A
- 2 x Arduino
- 2 x ESP-32 for wireless data transmission
- 1 x LED
- PC for receiving and storing data

The following below are equipment extras required for the Demo:

- Bat plushie
- 2 x HC-SR04 ultrasonic distance sensor for the bat plushie, working frequency 40kHz
- 2 x RGB LED for the bat's eyes
- PC connected to the bat
- 1 x motor for the model windmill
  Motor DC 12V 100RPM, 60:1 gearbox
- 1 x 9v battery for the motor in the windmill

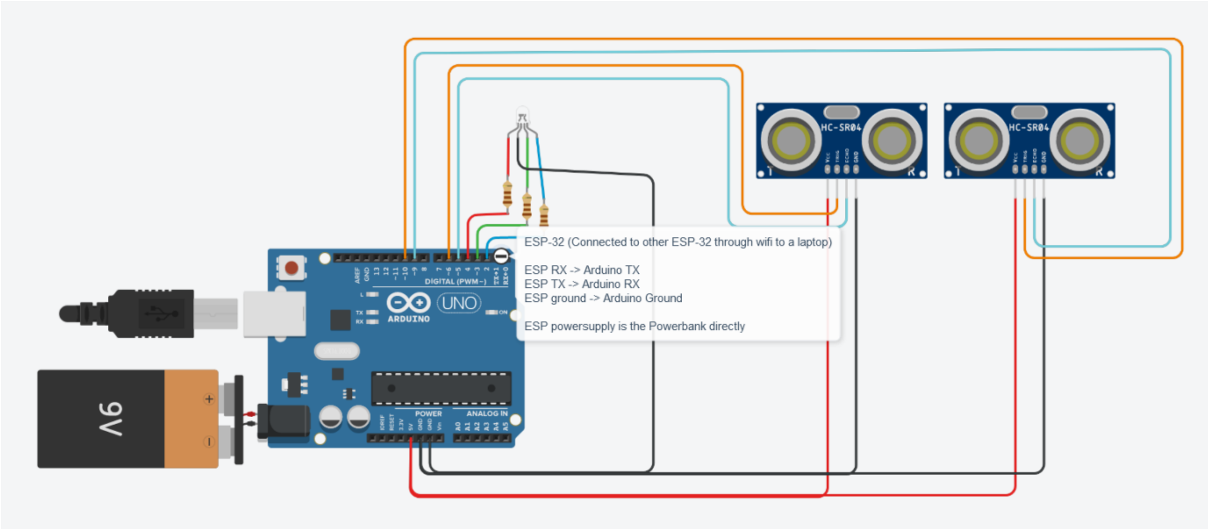


Figure 1.1. Circuit diagram entailing the used circuit

In the top figure the final circuit is displayed. In this circuit the two circuits (one for the bat and one for the windmill) are meshed together, to make the overview more clear. In reality only the bat circuit uses rgb LEDs (two LEDs) and the windmill circuit uses one normal LED. One can see in the figure the usage of the ESP-32, for wireless data transfer, which is only used for the windmill, since the bat is a dummy, whose only use is to help validate the concept. The bat will be hooked up to a computer via a cable.

**SENSOR CALIBRATION**

The planned ultrasonic sensor is the HC-SR04 ultrasonic distance sensor, which has a working frequency of 40kHz. Which is in between the range of the deterring frequencies, according to four different studies [35]. This means that our sensors should need little to no calibration as the ranges in which they operate are already within the scope needed.

**ENVIRONMENT- SPECIFIC REQUIREMENTS**

The device will be tested in a controlled environment, however it is possible to be implemented in a non-controllable environment when constructed with more expensive, out of budget, materials. This device will need a casing to protect it from weather conditions, specifically: wind, temperature and rain. The brain of the device will be an Arduino Uno. Aside from being connected to a power source, this Arduino will be connected to two ultrasonic transceivers (HC-SR04).

The Ultrasonic sensor inside the bat stuffed toy will be connected to two rgb LEDs in its eyes (to prove that the bat is sending and receiving frequencies, corresponding to different LED colors, where green means it is sending a frequency and blue means it is receiving the deterring frequency from the windmill). The Arduino will also be connected to an ESP32 so it can communicate with a laptop wirelessly. This entire device will be constructed on a model windmill made of wood, which includes a LED that lights up when it has received the bat signal and it transmits a signal back.

**DATA COLLECTION**

The data will be collected by the ultrasonic sensors. These sensors are microphones that are able to sense ultrasonic sound. When these sensors are triggered by the ultrasonic signal they will keep track of the amount of times they are triggered. Since the sensors only sense ultrasonic signals they will only sense the correct frequencies.

Every time a bat frequency is detected, it gets added to a counter, which keeps track of the total number of bats.

Every 10 seconds the program displays a graph that shows how many bats have been detected in these 10 seconds. Not only does the program display the amount of bats over time, but it also illustrates the pulses sent by the windmill and the bat.

**DATA ANALYSIS**

The sensors sensing the bat calls will keep track of the amount of times they have been triggered, this data will be analyzed to make a rough estimation of the bat activity in the area, this will not be very accurate but the main goal of our solution is mostly to save bats, and not count them. This data will in turn be put into a file that can be opened as an excel sheet.

**DATA UTILIZATION**

By keeping track of the total number of bats one can estimate the quantity of bats surrounding the area, and by sensing the number of bats over time there will hopefully be a decline in the amount of bats flying by the windmill, thus proving that it does repel bats.

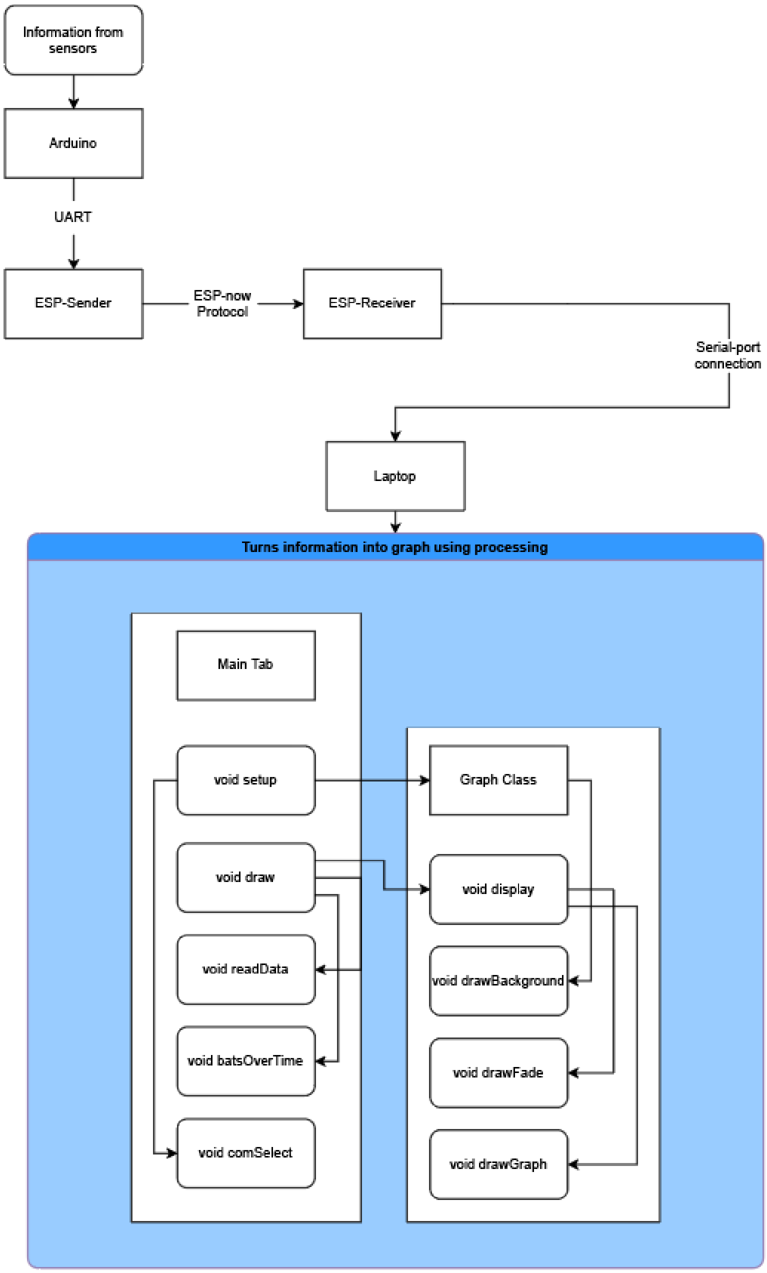


Figure 1.2. Data flow diagram/code diagram

The above figure displays the data stream from the raw information all the way to the graphs created, as well as the internal functioning of the program.

**VALIDATION OF PROJECT**

To check the validity of the project, the plan will be to make a miniature wind turbine and bat. There will be a sensor on top of the wind turbine, with an ultrasonic microphone to sense the bats soundwaves. Speakers from the ultrasonic sensors will be used to send ultrasonic waves to scare the bats off. For the demo, a bat plushie will be used as a substitute for the bat, with a different ultrasonic speaker inside of it, to send ultrasonic waves out like an actual bat would. The ultrasonic speaker from the bat will send out ultrasonic waves that in turn the sensor on the wind turbine will detect. With this explained, the validation plan of the project can be explained too. A few actions will be taken:

1. Data collection of the pulse from the windmill, to see if an actual frequency is being sent.
2. Data collection of the pulse from the bat, to check if an actual frequency is sent.
3. Data collection of the amount of bats sensed in a certain time period (10 seconds), to hopefully notice a decline in the amount of bats sensed in the future.
4. Data collection of the total number of bats counted, to conclude a rough estimate of bats in the area.

The sensors will send out and receive 40kHz, as this is a range that bats often reach. Realistically speaking a sensor that can receive the full range of frequencies a bat can make, 9kHz - 200 kHz, would be better, but this is an idea that would be more suitable in the actual funded big project, as the devices required are too expensive for a university demo.
Collecting data of these things will validate how much the solution actually works according to the predetermined plan.
With this the precision and recall can be calculated;

$$\text{Precision} = \frac{tp}{tp + fp}$$

$$\text{Recall} = \frac{tp}{tp + fn}$$

Figure 1.3. Formula used in calculating precision and recall

**METHODOLOGY UNDERLYING THE VIABLE SOLUTION**
The problem in question is the decline in bats. By specifically focusing on the deaths of bats caused by wind turbines and sending out a frequency that scares them off, it will hopefully decrease the amount of bats that die. Sending out a frequency will be done by a speaker and will only happen when the frequency of a bat is picked up by sensors (microphones).

**Time plan**

| Date | Normal time table | Ambitious time table |
|---|---|---|
| 16-12-2022 | Order parts needed | Order parts needed and start thinking of the software. |
| 19/23-12-2022 | **Software/Hardware:** develop the software for the sensors and speakers to work in tandem, possibly testing with the parts already in the proto kit as the parts might not have arrived yet.<br>**Design:** designing a 3D model in | **Software/Hardware:** develop the software for the sensors and speakers to work in tandem, testing with the parts that arrived before expected.<br>**Design:** designing a 3D model in Fusion of the prop windmill |

| | | |
|---|---|---|
| | Fusion of the prop windmill needed for the presentation, keeping in mind the space needed for the hardware to fit.<br>**Documentation:** Writing up the introduction.<br>Parts arrive before Christmas. | needed for the presentation and getting a laser-cuttable template keeping in mind the space needed for the hardware to fit.<br>**Documentation:** Writing up the introduction. |
| Christmas Break | - | - |
| 9/15-12-2022 | **Software/Hardware:** making the software for the wireless transfer of collected data and implementing it in the hardware.<br>**Design:** getting a laser-cuttable template for the windmill, laser-cutting the parts of the windmill and test-assembling the windmill.<br>**Documentation:** - | **Software/Hardware:** software and hardware development goes faster than expected leaving time for experimentation with three ultrasound microphones for more accurate bat locating and for checking the DAS bat sensing system to identify specific bats.<br>**Design:** Assembling the final prop.<br>**Documentation:** - |
| 16/22-12-2022 | **Software/Hardware:** final checks of the code and the wiring<br>**Design:** assembling the full windmill with the hardware inside.<br>**Validation:** testing the project to see if the bat call gets sensed and if it gets an accurate response.<br>**Documentation:** add a validation (chapter 8) and a conclusion (chapter 9) | **Everyone:** validating the final project with all the extra additions giving more accurate data.<br>**Documentation:** add a validation (chapter 8) and a conclusion (chapter 9) |
| 23/29-12-2022 | Demo market and archiving | Demo market and archiving |

The tasks will be divided according to a diagram that was made. This diagram shows that there will be specific people responsible for certain tasks with other people being the bridge between two tasks to help out in both and to make sure the two parts keep inline and operable between each other. There is also the team leader in the middle which is responsible for making sure the team operates smoothly and jumping in to help where able. The documentation encompasses the whole team as it is important that the people who worked on a part write what they did and how they did it to get a more accurate picture of the process.

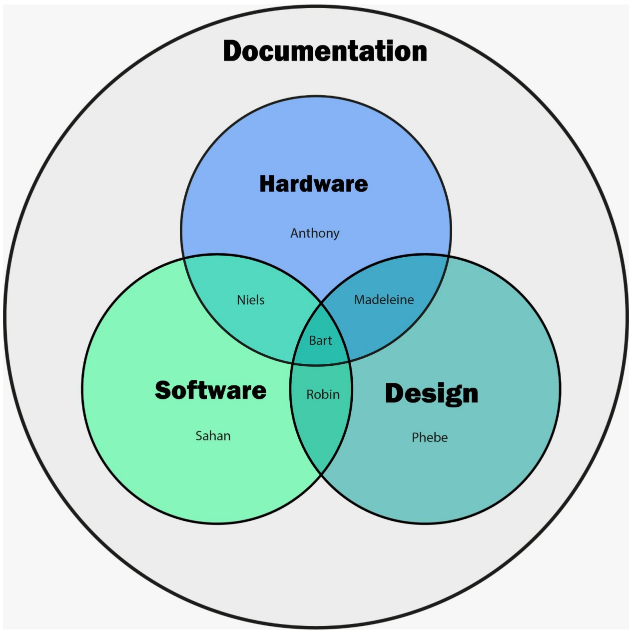


Figure 1.4. Diagram detailing the division of tasks among group members.

## Chapter 8: Validation

The way the circuit of the windmill and the circuit of the bat were tested, was together with the code, this was in an early stage where they weren't soldered yet, and still on breadboards. A regular LED would turn on if either the bat or the windmill were receiving the other's ultrasonic frequency. The two breadboards with the sensors were put opposite of eachother, on a distance of around 25 cm. The plan was to angle them towards each other to test if the LED would only actually turn on if they sensed each other and not anything else. (As can be seen in video attachment 1), this worked. Both the code and the hardware worked.

For the RGB LEDs the circuit got tested on a mini breadboard by adjusting the values of the different colors in the LED. The circuit worked with the LEDs in circuit. There was no resistor used.

The first soldering did not go exactly as planned. Soldering the circuit for the windmill and the Arduino part of the bats circuit went well, but the RGB LEDs did not work properly, so the soldering had to be redone. After this it turned out that the RGB LED pins were not corresponding to the color they were supposed to. This problem was solved by changing the wiring in the circuit (see video attachment 2).

As for the graph that would display the pulse of the windmill and bat: it works. However it was not able to actually be tested with the entire contraption. In theory the graphs work, they are able to display, as they were tested, just not with the actual circuit.

The entire programming works, not only have the graphs been tested, but the counter of the total number of bats and the counter over a certain amount of time. It has been tested over and over again, of course not with the entire circuit, as integrating the programming with the circuit did not work out as planned, as the circuit broke after only a few minutes. But it is now known that it would collect the proper data as the numbers of bats went up whenever the signal of the bat was received.

Making the ESP32 work was quite a challenge and took a while, but it ended up successful, so the ESP worked too.

The final product worked, but only for a few minutes, after this, without any changes having been made to the hardware and the software, it stopped working. There is no telling what exactly went wrong. A video was made before it crashed (see video attachment 3).

The validation process that was planned beforehand couldn't work out, as the program did not work long enough to test anything with. But given more time and better sensors, ones that are made for the purpose this project has, instead of ones within a much lower budget, the solution would likely have worked, based on the research of this project.

## Chapter 9: Results and Conclusion

As for results, it is unfortunately not possible to test the device in real life, as the sensors used are not able to detect the entirety of the bat range, for that a very expensive sensor is needed. One can also not forget the fact that most bats hibernate in winter, thus making it even more difficult to sense actual bats during the time this project took place.

The plan was to replicate a bat sending a frequency and our device sending one back, this proved to be possible, yet highly unstable with the ultrasonic sensors used. This led to wildly varying testing results, where the device would at certain points in time perfectly sense the dummy bat and then stop moments later. When it did work however, the software managed to count the total number of bats, the number of bats of a certain time period, the pulse of the bat and the pulse of the wind turbine.

From these results a few conclusions could be made, namely that the bat was sending out a frequency, that the wind turbine was sending a frequency back and that according to the pulse of the bat, the bat has received the frequency of the wind turbine. Then after the pulses being sent, there would be no pulses displayed as the wind turbine had managed to deter the bat.
One could also see a graph of the number of bats over a certain time period. The plan was to hopefully, if implemented in real life, see a decrease in the number of bats repelled, which would back up the goal of the project to deter bats from getting close to windmills.
At last, there was a counter that kept track of the total number of bats and evidently monitored how many bats there were in that area.

In conclusion, the theory behind the project was solid , as there are four studies that support the functioning of the project [35]. That being said it, if given a more expensive sensor made for the specific goal of the project and more time, it would have been possible to implement this project in real life.

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Video attachment 1 https://youtu.be/UH-2eddnzw0
Video attachment 2 https://youtube.com/shorts/laQHdWyyEB0
Video attachment 3 https://youtu.be/U16mTaQUFXc
Video attachment entire progress https://www.youtube.com/watch?v=Vk_vgfcRWS4