UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Team 6: goCrows

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Chapter 0: Introduction

Smart environments are modern solutions using technology to monitor and solve issues. In an age where climate change has disturbed many species, being able to monitor and regulate said species is an increasingly important duty. Through researching species and the differing circumstances that cause them to need monitoring and regulating, one species is to be chosen for closer inspection. For this project, the chosen species was the crow, an animal abundantly found in most countries in Europe. The crow is a very intelligent bird species which has increasingly moved to urban areas and tends to cause trouble when they have their young, especially in populated areas such as big cities. [34] Due to the issue of public disturbance in cities, crows, a protected species in the Netherlands, was chosen to be monitored. The team *goCrows,* consists of members Nina Björk Costa Håland, Niels Walraven, Kaya Veen, Femke Stockmann, Anna Hornman, and Maja Lamminga, all separated into modules of responsibility for the making of a solution to the chosen issue.

To achieve the goal of finding a smart environmental solution to the issue of redirecting a species without disturbing or harming them, several ways of monitoring are needed to work together. Monitoring systems such as infrared sensors, pressure plates, and sound recognition are potential ways of monitoring the presence of crows in certain areas without needing a person present. The goal is to redirect crows ethically and legally to unpopulated areas to integrate them further to their natural ecosystem where they will be with both their natural predators and prey. To solve the issue, a process of brainstorming of differing monitoring systems and ways of redirecting crows led to the broad idea of a monitoring system used to scare crows from trash cans, as trash is a large part of the diet of city crows [1]. After brainstorming, the research question of how to both monitor and safely redirect crow populations within cities was chosen to be researched and solved through the invention of a smart environment.

Chapter 1: Literature Review

1. Real time monitoring (RTM), using the geological location acquired by a GPS system, is being used in Kenya on 94 African Elephants. Data received by a cloud-based server or from a third-party IPA is being used in a custom-made monitoring application MovementMonitor. The processing of the data is being improved to accurately figure out whether an elephant has been killed by poachers or died of natural causes. In the future the data from the monitoring application will be used to determine the physical health and environment of the animal. [2]
2. The usual monitoring of insects is placing a series of traps and checking them manually after a certain amount of time. This costs a lot of work and is very inefficient. Software and image recognition algorithms can help make insect monitoring more efficient, by identifying insect species. Real-time and on-line pest monitoring systems could allow us to measure more and to measure better without too much human labor. There are limitations in the field, like cost, power supply and picture quality. [3]
3. Zoologists wanted to measure movements and social interactions between badgers. There were environmental sensors, active RFID tags were implanted in collars and RFID receivers picked up the behavior (movement from RFID tegs) which comes together in an RFID-WSN hybrid system. [4]
4. In Finland, about 51 cameras were put up around central lake Saimaa, to Photo ID the endangered Saimaa ring seals. Motion sensitive game cameras are being used to take pictures and the best ones are go towards the DISCOVERY data management system. The study was conducted in the main breeding area of the ringed seals. [5]
5. Automated wildlife recognition was experimented with in South-Central Victoria, Australia. The experiment achieved 90.6% accuracy for recognizing pictures of the three most common species in the area of experimentation. Using automated wildlife recognition can be implemented in order to help researchers process data gathered by ‘camera traps’. [6]

6. Unmanned aerial vehicles are used for detecting and counting multiple types of animal species. Research was done about whether the sound of the UAV would present difficulties in using them for this type of research. [7]
7. Detectability is an important factor in wildlife monitoring. Using a model for detectability predicts the species detectability and can help with monitoring the species more effectively. A detectability study on foxes in Eyre Peninsula, South Australia found that detectability was very low and depend on many factors. [8]
8. An IoT system is used in order to monitor wildlife around cities and the damage they create. This is then used to find a solution to limit the damage created by wildlife. The IoT system is used with the sustainable development goals of the UN in mind. [9]
9. To monitor the behavior of animals during a forest fire a drone with fire and smoke detectors was used. The drones collected information with high-resolution cameras and IR-cameras to make images that were obtained with a charge-coupled device. And last navigation sensors were installed. This is all to save time and money by replacing arial and ground surveillance. [10]
10. The Alaskan wildlife was threatened by non-native rats. These rats prey on other wildlife in Alaska, especially seabirds. Rats also assist in damage to crops and food stores, they contaminate food and animal feed. They spread diseases that can be dangerous to the health of humans and livestock. Rats are very destructive animals; they damage all sorts of property and have a big impact on human society. [11]
11. Deep learning methods were used to develop two frameworks used to identify wildlife, and in particular badgers. A dataset consisting of 8,368 images of wild and domestic animals was being processed by algorithms to ‘train’ the software, with the aim to develop an automated image classification algorithm which can identify still images containing badgers. [12]
12. A two-year study of leopards in central Africa. It reviews the sustainability of different methods for various study objectives and in particular remote photography survey methodology. Monitoring the leopards is being done by identifying tracks, genotyping

scats and hair and lastly by remote photography. The cameras used were the TrailMaster and the CamTrakker. [13]

13. In north America 20 different species were being photographed with a motion triggered camera trap, at 1,000 locations. A Deep Convolutional Neural Network (DCNN) algorithm was used to recognize movement from animals. Where a Bag of visual Words (BOW) system was used in the past, now, the DCNN algorithm has more promising numbers. [14]
14. Faunawatch is creating an AI system that can monitor animals and recognize when an animal is on camera to automatically send that feed to researchers, or even directly identify which animal and species it is. Additionally, the AI system can protect the animals too, by identifying poachers in real time and directly sending that information to rangers who can act immediately. This not only counts for land animals, but also for marine animals. One of the systems they are working on will identify boats and compare to a list of illegal fishers to find out if it is one or not. [15]
15. The purpose of the Dutch Wildlife Health Centre (DWHC) is to enhance knowledge and expertise in wildlife health in the Netherlands. This will serve to provide scientifically based information for political and practical decisions concerning public health, wild and domestic animal health, and nature conservation issues. They check if any diseases go around in wildlife, and if they can be transferred to pets and humans, or the other way around. They also check what impact the animal or its disease will have on the environment and on the population of the animal. [16]
16. This study by the university of Wageningen is about the recent opening of a crossing between the Hoge Veluwe national park (HVNP) and adjacent conservational parks. The management of HVNP wishes to monitor the consequences of immigration and emigration of ungulates (animals with hooves) via these openings. The ungulate species currently occurring in HVNP are red deer (Cervus elaphus), Roe deer (Capreolus capreolus), Wild boar (Sus scrofa) and European Mouflon (Ovis orientalis musimon), while the openings may lead to immigration of Fallow deer (Dama dama). This report aims to facilitate ungulate monitoring in two ways: by compiling data that can be used

to produce baseline information on the current composition, density and distribution of the ungulate population, and by designing a camera-based monitoring system that allows for detecting changes in population levels and habitat use over a period of 4 years. [17]

17. The study focuses on monitoring Raptors and Owls. These two species were chosen due to their roles as top predators which makes them the easiest to use to monitor changes in wildlife populations and ecosystems as they are often sensitive to environmental changes and are easy to monitor. The MEROS program and Birdlife International both heavily contribute to the monitoring of Raptors and Owls. [18]
18. The study explores the monitoring of ants in Brazil from other articles written in either English or Portuguese. The general conclusion is that ants are a cheap and accessible form of monitoring changes in wildlife and effects of climate change. The primary methods of monitoring ants were hand collecting and pitfall traps. The monitoring of ants in papers both in English and Portuguese were dated back to 1987. [19]
19. The population of crows in New York were monitored to find correlation between dead crows and disease in the area. A correlation between dead crow density and disease among people was found. The threshold chosen was 0.1 dead crows per square mile and the areas with this threshold had on average 2.0–8.6 times the risk for disease compared to those areas with less than 0.1 dead crows per square mile. [20]
20. The current model of monitoring penguins with physical monitoring devices attached was proven to harm welfare and performance. The study follows the use of a visual computer system to track penguins in Robben Island, South Africa as a way of solving the issue of penguin welfare and physical monitoring devices. The study found success in using this method for monitoring that were comparable or more successful than the use of physical monitoring devices formerly used. [21]

Chapter 2: Identification of General Problems and Challenges

1. Being able to detect foxes is difficult since it is unclear where they are at what moments, in other words their detectability. The unclarity in the detectability makes the monitoring inefficient. (Chapter 1.7)
2. Physical monitoring devices can cause harm to the wellbeing of penguins, this can create unreliability for the data gathered from the monitoring devices. (Chapter 1.20)
3. Having to manually go through all the image data of the leopards is very inefficient since it takes a lot of effort and time. (Chapter 1.12)
4. If you want to create a system that reduces human labor, you will have to deal with the limitations of the power supply. Monitoring insects using cameras can be tricky since those cameras need to be working without interfering with the research too much, it costs a lot of power. (Chapter 1.2)
5. The behavior of animals is unpredictable during forest fires. This makes it difficult to monitor them with cameras, because of the placement of the cameras. (Chapter 1.9)
6. The unmanned aerial vehicles (UAV) make a lot of noise. This noise might cause the animals being observed to flee from the UAV. If the animals are fleeing from the UAV, it could mean that the data gathered on the animals is not very reliable. (Chapter 1.6)
7. Using machines or deep learning to recognize animal species is a bit of a challenge since it is not foolproof and does not have 100% accuracy identifying animal species. This is seen as well in Australia where there is a 90.6% accuracy for recognizing species. (Chapter 1.5)
8. As the ungulates immigrate and emigrate a lot between the Veluwe and other parks the location of the animals is unpredictable. (Chapter 1.16)

Chapter 3: Identification of Relevant Problems

Crows

Crows can be a disturbance in large cities. They can create a lot of waste and even attack people. When crows have their young, they become more hostile and will attack people more easily. [22] Crows will eat most things, including people's trash. Thus, they can create issues because of their numbers in cities where there are a lot of people, so also a lot of food for crows. It can be an issue to control the crow population, as they are a protected species and thus cannot be harmed in efforts to relocate them. [23]

Insects

There is no indication of how many insects there are. When insects are counted this usually happens near flowers but not in fields of grass which makes it more difficult to have a clear indication. Rapid changes are a factor for the big changes in the number of insects. For example, the quality of water used to be bad in the Netherlands so there came regulations. Which made it possible for certain species to increase in number like the caddis damselflies, dragonflies and water beetles but the number of mosquitoes decreased. [24]

Squirrels

The number of squirrels in the Netherlands has significantly decreased over the last few years. Mainly because of the scarcity of food, a lot of squirrels don't survive the winter. The scarcity of food is caused by the rainy springs as the rain hinders the pollen of oak trees. This causes there to be fewer acorns, one of the primary food sources of squirrels. [25]

Fish

In summer, fish are dying since there is a shortage of water, for this the VISambulance can be contacted who plan on saving the fish. However, the current system is slow and ineffective. If fish were to be monitored, a system like the VISambulance could be improved by automatic counting and data of the water supply. [26]

Bats

Bats in hibernation are monitored in a standardized way, allowing for the data collection all over Europe to get a better idea of the (trends in the) bat population locally or throughout the entirety of Europe. However, data from one single observation is not accurate enough to use, so follow up observations in the same/surrounding area are always necessary. [27] Places where bats hibernate are usually caves or dark areas with lots of hiding spaces. Because of this it can be difficult to fully count every bat that is present (with a camera or in person).

Chapter 4: Problem Selection and Motivation

The selected problem is the disturbance by crows in cities. Crows are an advantageous choice to monitor as they can be found in most places around Europe.

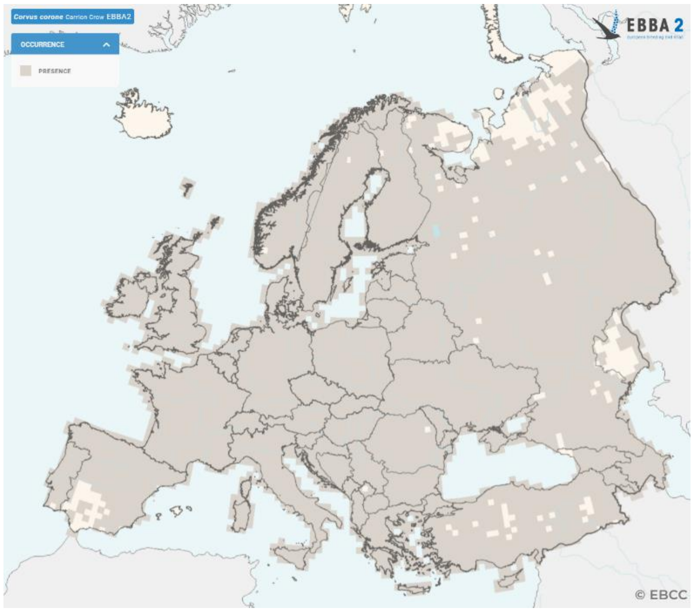

Figure 1: Carrion Crow (Corvus Corone) presence in Europe [33]

Monitoring them can have a greater impact than monitoring, for example, bats as they are not know to cause as much disturbance. The issue is also relevant as anyone can encounter hostile crows and be inconvenienced. Keeping track of the subjects is important and thus the species chosen to study were crows, a species that acts less erratically than squirrels, as this choice makes gathering data more efficient and reliable. The issue of crow disturbance is seen in both urban and rural areas, however as a smart environments project, being able to create a unique solution to this issue in farms for example would make for a solution quite similar to that of the scarecrow which is already used. Since most crops at this time of the year are also not in season, most of the food sources that lure crows in are not in farm areas, but rather in urban areas.

The issue of crows acting hostile is a potent threat to local communities and needs to be properly addressed. At this moment the only action cities have taken is putting up signs that tell people to be careful. [28] They cannot be forcibly removed, trapped or shot, as the black crow is considered a protected bird species. [32] The solution to this problem must be passive as most methods can be considered a disturbance to the crow population. There is a need for non-interruptive monitoring and regulation of this species, which will be addressed and explored further in later chapters.

Chapter 5: Potential Solutions

The app

A potential solution is to create an app in which people can communicate with one another where there are a lot of crows. This way, the 'hotspots' for crows can be found. When people know where they are and can see in the app that there are a lot of crows at that moment, they will know it might be better to avoid going there now. Another possibility for the app is that people can easily contact pest control if the crow problem gets out of hand at a certain place or that the app keeps track where the most 'hits' are and shares that data with pest control automatically when it reaches a certain threshold.

Luring with food

Crows are intelligent and can be trained. Knowing this information gives the possible solution to lure crows away from crowded places. If food is placed at a certain place at a certain time periodically, then the crows will learn to come to that place at the right time. The crows can be monitored using cameras that detect and count the number of crows present before and after the feeding.

Motion detection- playing sounds

Crows tend to flock around trash cans in search of food or in park areas such as benches. To ensure that crows do not loiter in heavily populated areas, sounds could be played to scare them off. Through attaching a motion sensor, the sound that activates whenever crows are around will not be a constant disturbance to the surroundings. A possibility for the choice of sound would be crows being attacked as this will ensure that the crows feel threatened enough to fly away from the area. When the sound is played the expected outcome would be crows flying away from fear of the threat of being in danger.

Bye-Bye crow system

Crows are very sensitive to shiny objects; this can be used to scare them away from common places such as terraces. To scare away crows without disturbing everyday life too much, machine learning can be used to spot whether there are crows or not. By recognizing patterns in the crows' bird call it is possible to detect them and scare them away by revealing a disco ball as can be seen in figure 1. These anti-groovy birds will scurry away without causing too much disturbance. [29]

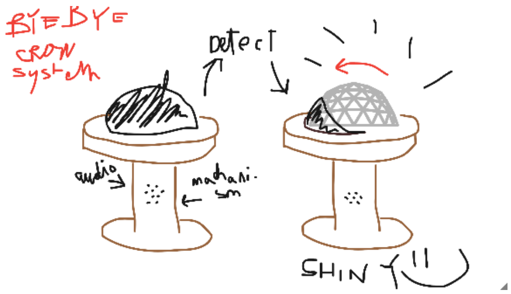

Figure 1

Flappy trash cans

Crows don't like flappy, reflective surfaces, they get scared by it. And crows often find food scraps near trash cans in cities. [30] If the amount of food scraps crows can eat out of the trash cans is limited, crows might roam the cities less. Reducing the amount of food scraps is not a viable option but collecting them can be made more difficult. If the trash cans were to be "guarded" by reflective air dancers as seen in figure 2, the crows would be less likely to approach the trash can. Letting the air dancers dance continuously would be a waste of energy and might bother citizens, so it is of quite some importance that the system only turns on if a crow were to be close by. For this, some monitoring would have to be done. A pressure activated sensor could be placed in the opening of the trash can, in such a way that it would be activated when a crow would be looking into the trash. So, whenever a crow is ready to dive into the trash, the air dancer would start to dance and scare the crow away.

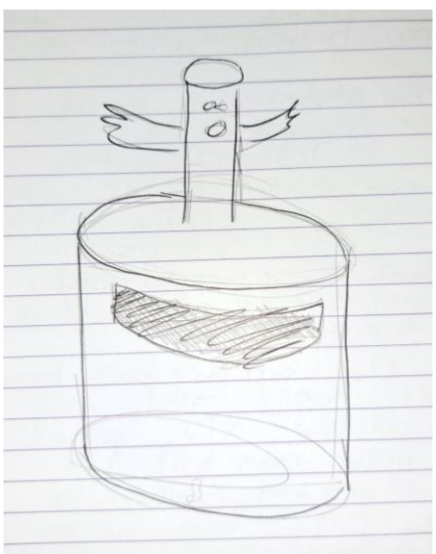

Figure 2

Bin lids

Crows usually sleep in large roosts consisting of huge numbers of crows, and in the morning, they break up into smaller groups and find food around the city. Returning to the same spot and group again that night. They like to sleep in large trees, making parks an obvious place to look for them, as many large trees are usually close together there. This would be a good place to set up infrared cameras to try and monitor some of the movement and sleeping patterns of the crows. [31]

One of the best ways to lure animals away from an area is by removing their food source, leading to them finding another one. One of the things that crows like to look for food in is trash, being able to open closed bags by themselves and spreading the inside all over the floor to find some food. Because of this, a good way to get them to move is by cleaning up the city and putting lids or push doors on bins, so they are still usable but not by crows.

The all in one

The idea of using machine learning to monitor the crows' call to detect whether there are crows or not is used. In case there is a crow, an Arduino will be used to activate the system to turn on the flap of the flappy trash can.

Chapter 6: Solution Selection

The light smart bins (the all-in-one)

The selected solution is the idea of all-in-one, a new solution based on other separate ideas and the feedback received from the presentation that was done.

A lot of the solutions had interesting parts to discover and use during the project. However, separately they might not be as effective as when they would be combined. That is why the all-in-one solution takes ideas from the Bye-Bye Crow System, the Flappy trash cans and the sound system.

Taking the different parts from different solutions makes the ‘all-in-one' solution promising as the combination should make it more feasible and effective.

A smart garbage bin will be designed, preferably with one of the university bins, otherwise a wooden bin will be made with laser cutting.

Input will be taken from infrared sensors and pressure plates to determine whether a crow is stealing food from the bin. After this is confirmed, a “lightshow” will be set up inside the bin. The top part of the bin will be a reflective service, on which LED attached to the top will shine. This will confuse the bird and scare it away. Another possibility is to implement machine learning to detect any crow sounds around the bin to activate the LED to scare the birds. All three sensors will ideally work together to detect and frighten off crows.

In case the system is faulty a possibility would be to implement a button for the surrounding civilians to press in case they are experiencing direct disturbance by crows.

Chapter 7: Methodology

Basic scenario vs ambitious scenario

The initial idea, thus the basic scenario, is to have an infrared sensor and pressure plates to detect whether there is a crow taking trash from inside the trash bin. The crow will trigger the light system intended to scare it away. The light system is made up of a reflective surface on the top on the inside of the bin and has a few led lights directed at the reflective surface that will turn on when the system is triggered.

For the ambitious scenario, the idea is to add a sound recognition system to detect whether it is indeed a crow that is triggering the system. A type of human vs birds' classification. This can make the system more effective and reliable, thus making the data more reliable.

The solution is a system that works with the information gathered by sensors, that then generates an output. The gathered input is about temperature, weight and for the ambitious plan it also includes sound of crows. The output is triggering a system that will scare away the crows that are picked up by the system. The system is created to better the lives of everyday people by scaring away disturbing crows. Altogether, this makes the solution qualify as a smart environment.

Equipment and data collection

To make the system infrared sensors, pressure plates, an Arduino, a circuit board (breadboard will be used when fist setting up and trying out), reflective surfaces, for example foil, LED lights and a casing for the electronics will be needed. Firstly, to protect the electronics from the weather and secondly, to protect it from possible vandalism. Also, when people throw away their trash, it might damage the system if it is not protected by a casing. It should also still be possible to empty the trash bin without worrying about damaging any of the electronics. The system will be installed on a trash bin, so a trash bin will be needed as well. The hope is to be able to use a trash bin of the University. For the ambitious plan, a microphone, software and data to analyze the crow noises will be needed additionally. Additionally, the plan is to be able to wirelessly transmit the data from the bin to a laptop, which will be done through using two Arduino's with an NRF24L01 wireless transceiver.

Equipment list:

- Sound detector, microphone, soldered connector, SparkFun SEN-14262, borrowed from Alfred
- Wireless transceiver NRF24L01
- Arduino nano 33 BLE Sense (borrowed from third party)
- Pressure sensor 2SMPP-02
- Infrared thermometer MLX90614

For the basic plan, the data analyzed will be the weight, by the pressure plate, and temperature, by the infrared sensor. This data will be collected throughout the day. The data collected by the sensors will be collected and compared to each other. If both the data by the infrared sensor and the pressure plate meet the expectations to be a crow, the system will be triggered (turned on). The input from the sensors will be automated to return true if both validations have been met. If the ambitious plan is also implemented, that input will also need to be validated based on data, which will also start the system. All this data will be controlled within the Arduino to actuate the lights. The testing of the validity of the system and data collection will be done on the 23rd or 24th of January. Placing the trash can with the integrated system inside in a park or around the university while waiting for a crow or any bird to approach the pressure plate and sensor.

Demonstration and validation

To demonstrate and validate the solution, a demonstration of the workings of the trashcan system will be given. During this demonstration, the idea is to heat up water bottles of about 400 – 600 grams to simulate the crows. This is for the presentation of the basic plan. If the ambitious plan is implemented as well, a demonstration will be given by playing recordings of crow sounds and showing how the sound recognition system works.

Through finishing the methodology, a general plan and structure was made for the project. With a more realistic approach using pressure plates and an infrared sensor, there is a realistic and simplified method of achieving the goal of monitoring and moving the crow population away from populated areas. Through assigning modules to each team member, it is ensured that each member must take responsibility for a certain part of the project, and it is made clear whenever a member has not contributed sufficiently. The modules will be chosen based on the answer chosen for each member's strengths and weaknesses. Each member will also be expected to learn more from the modules they struggled with before the project. With a clear plan for collecting and evaluating data, the success of the proposed solution will be tested and assessed along with the demo testing.

Modules

1. Team leading
    a. Coordination, presentation, feedback.
2. Documentation
    a. Updating data when new developments are made.
    b. Data presentation (graphs), report questions.
3. Testing
    a. Collecting data, calibrating sensors, training neural network(sounds).
4. Programming
    a. Data collection, data input, programming (Arduino), training neural network(sounds).
5. Hardware development
    a. Sensors, wiring, setup of infrared sensors, preparing final demo.
6. Design
    a. Make a lid for the trash can, reflective surfaces, setup/ positioning, casing.

The main contributors will oversee one module and be supported by the team members with multiple modules assigned to them. Each module is based off the general skills needed for this project and was assigned based on the strengths and weaknesses of each member. All weaknesses within the group will be kept in mind and the goal will be to improve these skills as a group.

Nina	**Niels**	**Kaya**	**Femke**	**Anna**	**Maja**
Team leading/ Documentation	Design	Programming- main contributor	Hardware development- main contributor	Design -main contributor	Hardware Development
Testing	Testing				Programming
Weakness: programming	Weakness: Programming	Weakness: Hardware	Weakness: Programming	Weakness: Team leading	Weakness: Documentation

A schedule for the last month has been made to ensure the efficiency and accountability of each member in finishing the required work within set deadlines.

Schedule:

<table>
<tr><td>PERSON</td><td>Nina</td><td>Niels</td><td>Anna</td><td>Kaya</td><td>Maja</td><td>Femke</td></tr>
<tr><td>WEEK 5
12-16 December</td><td colspan="6">Finish chapters 1-7 of the documentation report.</td></tr>
<tr><td rowspan="2">WEEK 6
19-23 December</td><td colspan="6">Make corrections to the report</td></tr>
<tr><td></td><td colspan="2">Starting on thinking of the design requirements.</td><td>Starting on programming the processing of data of the Arduino.</td><td colspan="2">Starting on thinking of a circuit that can handle all the functions it needs to.</td></tr>
<tr><td>WEEK 7
9-13 January</td><td>Figure out how to be able to simulate a crow for the demonstration.</td><td colspan="2">Incorporate the hardware into the design and start executing it.</td><td colspan="2">Finish the program and make sure it works with the finished circuit.</td><td>Finish the circuit and maybe solder a few things for sturdiness.</td></tr>
<tr><td rowspan="2">WEEK 8
16-20 January</td><td colspan="2" rowspan="2">Finish the last two chapters of the documentation report.</td><td rowspan="2">Look into possibly necessary adaptations for the microphone in the design.</td><td colspan="2">Program the sound recognition system</td><td></td></tr>
<tr><td></td><td colspan="2">Add the microphone to the Arduino circuit.</td></tr>
<tr><td rowspan="2">WEEK 9
23-27 January</td><td colspan="6">Dotting the i's and crossing the t's.</td></tr>
<tr><td colspan="6">Friday 27th of January: DEMONSTRATION DAY</td></tr>
</table>

Chapter 8: Validation

Sensor validation and results

Temperature sensor

The temperature sensor used is the Infrared thermometer MLX90614 with a standard accuracy of ±0.5ºC in room temperatures.

There are difficulties with sensing accurate temperature. Ambient temperature is measured higher than actual temperature. A human hand has a high range of measured temperature depending on distance and person. This temperature ranged from 24 degrees Celsius to 50 degrees using the infrared thermometer. The MLX90614 has the most accuracy in temperature when it is sensing an object 3-5cm away which explains the high temperature ranges.

Possible solutions in case this continues to become an issue, measuring a crow from the exact distance would be impossible. Since the change in values retrieved from the sensor would vary way too much.

Pressure sensor

The pressure sensor used is the 2SMPP-02 pressure sensor with a range of 0 to 37kPa.

The pressure sensor must be put into a tube on which pressure is put for the sensor to recognize. It essentially senses the difference in air pressure in the tube. The tube needs to be the correct fit, so that the pressure sensor is sealed off and is airtight.

Sensor and LED collaboration validation

The infrared sensor and pressure sensor should work with the light system activated at a predetermined threshold. The pressure sensor sends out a standard value. If the value gets higher, something is standing on the tube. The value will be linked to the weight of a crow, 400 to 600 grams. If the value is higher or lower than the base established with the 400 to 600 grams, it will not trigger a reaction. For the value for the threshold of the infrared sensor cannot be chosen yet, since there is too little information about the outer temperature of the crows. If the outer temperature of the crows was known, the lower threshold would be 1.0 degrees under the average temperature and the upper threshold 1.0 degrees over the average temperature. If the temperature falls within these parameters and the pressure sensor gives a correct value, the LED system should activate and flash.

Demo Testing process

The ambitious approach to testing was to use actual crows through placing the trash can on campus grounds in Twente. This was attempted and the product was monitored for two hours without any crows approaching the sensors. A likely reason for this is that the presence of people around to monitor the trash can scare any birds that would have approached the product. Due to the misfortunate need for a presence to activate the code, this issue could not be handled within the time constraints. With more time to work on the trash cans, the sensors would be able to work independently and monitor crows without human supervision.

Instead, the hand approach was chosen again to test the ability of the sensors to detect pressure and heat, albeit not from an animal. When a hand was placed on the plate and added pressure to the opening of the trash can. The infrared sensor picked up the existence of a living being and activated the light system. The LEDs were very bright. They were, however, not seen as a nuisance to the surrounding people.

Chapter 9: Results and Conclusion

Potential scope- from global to local

The idea for this project was to implement smart environments into the very common item that is a trash can. The low level of disturbance from the light system means that the trash can be easily installed in any public area. For this project, the scope can be as large as global, as the product can be used in any country that struggles with crow disturbance. For a more realistic goal, the trash cans could be implemented easily in the university or city center. However, they are too expensive to implement. To make the project work better, more sophisticated sensors are needed. This could drive up the cost significantly, so the project would not be fit for global use. Therefore, with more time to fine-tune the aesthetics and practicality of the product, it could be integrated into the trash cans of the local community of Enschede.

Plan versus outcome- a modular approach

Conclusion for Documentation and Testing

For the modules of documentation and testing, time constraints were a challenge as a large part of these modules depended on the other modules being finished. Finding ways to test the sensors, before a holistic program was completed, was a hurdle that had to be crossed. This was done by using a hand to determine the distances the temperature sensor could recognize as over 28 degrees. This was a simple way to test the sensor without having the pressure plate ready as a hand could also be used to apply pressure while being in the correct position to be recognized by both sensors. The same approach became the final way of testing the entire product, as crows did not approach the trash can, possibly due to the presence of people nearby observing the trash can in an attempt to monitor the testing.

Conclusion for Design

For the design module communication with the hardware module was incredibly important. As that module had its difficulties, it was important to create a design that was adaptable and could be changed quickly if necessary. The first idea was a simple box to put all the hardware in so that it could be safely stored, while also still easily accessible. This design was based on certain trashcans around campus. However, it turned out that a different type of trashcan had to be used, so a last-minute 'lid’ for that trashcan had to be made. The design for the lid was made in such a way that the previous design for the hardware could still be used, since easy access was still a requirement from the hardware module. Furthermore, it had to incorporate a way to use all the sensors safely and efficiently. This meant space for the temperature sensor to be attached to the lid and a contraption to use the pressure sensor and its tube, without making the lid too extravagant. Lastly, the inside of the bin lid was covered in aluminum foil to enhance the brightness created by the LEDs.

Conclusion on software

Firstly, it was important that all the sensors’ data was correct and could be used properly.

There was the issue of the infrared sensor. It was quite difficult to implement as it was theoretically able to work with multiple libraries. Many libraries were tested, however, some were a bit outdated and the Adafruit_MLX90614.start function did not respond properly. Eventually the MLX9061*4* Library was used instead of the MLX9061*5* Library, which seemed to fix the issue since the data received was clear from the sensor afterwards. The code of this was quite simple, however, figuring out how and which library to use and how it worked, which methods could be used etc. was a challenge.

After this some variables for the other data and a Boolean were made to make sure the right limits were set for the sensors to have ‘spotted’ a crow. It was decided for the temperature that the object's temperature must be a certain amount higher than the ambient temperature. In the beginning of the process a potentiometer was used as a substitute for the pressure sensor since this sensor was still being worked on.

For the pressure sensor the data from the sensor had to be read, this was done with analogRead(pressureSensorPin).

There was the option to send the data from the running Arduino to a computer. An attempt at working with a radio-based device was made, however, even after searching the internet, which contained videos and code of people who did make it work, earlier projects and libraries, this was not successfully implemented. Because of this the decision was made to switch to an HC-05 Bluetooth Module to connect both devices.

Conclusion on Hardware

The hardware of the project consists of three electrical circuits that are connected to the Arduino and the pressure sensor tube. Every part presented its own problems.

First, the sensors, the pressure sensor and the temperature sensor, were troublesome. In the Programming and Physical Computing lectures, sensors such as buttons, potentiometers and LDRs were taught. The way of connecting these sensors is not exactly the way of connecting the sensors used in the project. Through a lot of research and trial and error together with the software department, connecting the temperature sensor was made possible.

The pressure sensor was an even larger hurdle to overcome. There was difficulties with finding out how to connect the sensor. In an attempt to find out, a source that used another pressure sensor in combination with a LM358N op-amp was found. Since the pressure sensors looked quite similar on the datasheets, an attempt was made to make the circuit of the source work. The equipment list differed as it consisted of a LM358P op-amp as opposed to a aLM358N op-amp. After translating the datasheets to tangible data on the pins, the circuit of the pressure sensor worked. The soldering of the pressure sensor went badly. One of the pins kept breaking off, which lead to it only being a little nub at the end. An older CreaTe student suggested a small, printed circuit board, this worked like a charm.

The LEDs offered the least problems. White LEDs were used that had a different forward voltage and needed more current than expected, this required revision of the initial calculations for the power source and the resistors. Connecting the LEDs with a transistor went smoothly as this had been taught in Programming and Physical Computing. Since there is a lot of aluminum foil, they had to be isolated correctly, this was easily done with duct tape.

Lastly, the tube that is connected to the pressure sensor was quite troublesome. The first tube was not easily made airtight. Hot glue ended up being used around the ends, only to find out pressure difference could not be read because of the hard tube. Alternatives were searched for and three flexible tubes of different sizes were found at Technical Medicine. They worked better and were easier to make airtight. The tubes were worked on in the last week before the demonstration. With more time, an attempt at trying to make the tubing out of vacuum seal plastic would be made. The plastic is very sturdy but also very flexible, so it will not rip, and it will give clear readings. The vacuum seal plastic is made to be able to melt together, making a tube is very achievable. A prototype was made that does a good job at inflating and being pressed. The next struggle would be making this tube airtight against the pressure sensor. This may be done in the same fashion as the flexible Technical Medicine tubes.

Plan versus outcomes- a holistic approach

The proposed product went through many changes, both practical and aesthetical. Although the ambitious plan of implementing a sound detection system was not achieved, a working prototype which successfully implemented sensors was made. All modules were put in positions where there was a need for thinking outside the box and for adapting to new circumstances and to adapt to the work made by the contributors of other modules. A final product was made, using a trash can owned by the University of Twente, casing made by the design module and the efforts of all contributors of this project. This final pro

duct had working sensors connected to a lighting system which worked when tested with a human hand and theoretically a living crow. With many trials and tribulations, a solution for the issue of crow disturbance in urban areas was made using the principles of smart environments; an invisible computer integrated into a daily life object in efforts to solve one of the many problems humans face in society.

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