SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Go Wild!

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Chapter 0: Introduction

The project of module 2 is about smart environments. On a daily basis the wildlife problems happen without notice. In this report, starting with researching the common wildlife problems around surrounding areas, the one specific problem will be determined with the potential solutions. After the topic is decided, the ultimate goal of the project, overall design and monitoring method will be explicitly explained. Based on the collected data and test results validation, the final solution with the visual simulation will be explicated in conclusion. The problem to be investigated in the experiment is the affection of the city lights on habitat loss of the insect. Excessive artificial light or light pollution has become a widespread problem in modern society. It has been shown to have a negative impact on the variety of organisms, including insects, which play vital roles in many ecosystems as pollinator, decomposer, and food for other species. The insect behaviour will be monitored on different light conditions with the sensors and camera in the relevant way to the smart environment, and the potential solutions for mitigating the negative effects of light pollution will be explored with the analysis of data collection.

Chapter 1: Literature Review

Before starting a project, it is required to have knowledge on the topic. Wildlife is a hugely broad topic, thus research is needed. The undermentioned 20 paragraphs are summaries of different publications that were judged as relevant foundation for the start of the project.

Insects

Automatic life-long monitoring of individual insect behaviour now possible [1]

This paper explains the development of a small Radio Frequency Identification(RFID) chip. This chip can recognise 18*10^18 tagged(tagging happens by humans) insect individuals the size of an ant and larger. The chip can be placed in the wild and will send data of the insects' location and the time it was spotted to a database. This approach gives great insight into the behaviour of insects, allowing scientists to study the insects activity & location.

Advantages: Remote, (mostly)passive data collection, collects a lot of data.

Disadvantages:Animals need to be caught first to be tagged and data collected is mostly about behaviour, and less about the amount of animals.

Perspective and Promise: a Century of Insect Acoustic Detection and Monitoring [2]

This paper discusses the use of acoustic sensors to monitor insects over the last century. It discusses how different factors of the sensor influence how well these sensors can detect insects. Some of these established factors are the place of the sensor(in wood, earth or other substrates), frequency range, sensor type(vibration sensor vs microphone), assessment duration, type of insect(e.g. wood & grain insects) and the distance between sensor and insect. The paper judges acoustic detection to be a promising technology for insect monitoring.

Advantages:Passive data collection, collects a lot of data, nondestructive, automated detection, detects population size.

Disadvantages:Very technical, potential problems distinguishing sound(because of distance, similar sounds for different insects, noise, etc.)

Successfully Implementing a Citizen-Scientist Approach to Insect Monitoring in a Resource-poor Country [3]

This paper discusses the involvement of citizens for insect monitoring in a resource poor country. It talks about the hurdles to overcome when doing this, such as poor education, lack of existing groundwork and lack of equipment/resources. The success the title references comes from an approach that combines the government(whose goal is to meet the biodiversity targets) and local schools(whose goal it is to educate a largely poor population) which was applied in South Africa to track ant populations. The big advantage of this approach is that data on animal populations is collected, and additionally, the citizens are more aware of biodiversity and its importance.

Badgers

Seasonal variation in the food habits of badgers in an Alpine valley [4]

The aim of this paper is to present a picture of the seasonal variation of the badger trophic niche in a typical Alpine ecosystem at the upper limit of its altitudinal range in Europe(around 1600-1700m). These ecosystems are strongly seasonal in terms of climate and food availability. The food habits depend on the climate, so this study gathered 76 faecal samples in the period between March 1990 to October 1991. During the winter no samples were collected due to the harsh climate that forces the badgers into their den. The badgers were thought to be "earthworm specialists". But this study shows that is not the case, because during rigid seasons, the earthworm availability is not sufficient to rely on them for a whole nutritional requirement. This study shows that the badgers are opportunistic animals, which have to adapt their diet to food availability.

Foxes

Biogeographical patterns in the diet of an opportunistic predator: The red fox *Vulpes vulpes* in the Iberian Peninsula [5]

This study relied on different other studies, where the diet of foxes in different places of the iberian peninsulas was taken into consideration. They chose the iberian peninsula due to the presence of atlantic, mediterranean and alpine biogeographical regions and due to the fact that it is characterised by environmental heterogeneity. They show how different studies can be blended together and with the use of graphics how they analysed the results. Which shows that the foxes are a generalist predator, who uses the resources offered by the territory, these can change based on geographical variables, habitat type and season, which affect the availability of alternative potential foods. The main conclusion of the study is "Understanding these patterns in the feeding ecology of the red fox, the most abundant carnivore in the Iberian Peninsula, will facilitate the understanding of the geographical variations in its abundance and behaviour, and improve the management and conservation of this species."

Deer

Monitoring deer populations and assessing deer damage [6]

This paper discusses a research, made simple and available for everyone that wants to start monitoring deer. It's a step by step guide, but it's well explained and you can see that there's a depth of research and categorization behind it. It provides reasons on why you could possibly want to monitor the deer, including the best moment when to look for them. They suggest different methods with which you can identify the presence of a deer nearby. They also guide you with useful information on how to set your camera trapping, drones and more. In this paper there's also a suggestion to use an app to keep track of the number of exemplares, and share them. In this way the research can be even more deep and accurate.

Squirrels

Monitoring small and arboreal mammals by camera traps: effectiveness and applications [7]

The paper defines camera trapping of the small and arboreal mammals. It states that camera trapping monitoring is not widely tested on the smaller mammals when it should due to it being more non-invasive data collection. Two cameras are placed on the trees and record 24 hours per day. The hairs of the mammals were checked in the hair tube for further analysis and identification of the mammal. Then according to the gathered data the pattern of the daily life of the mammals is determined without any human contact.

Monitoring Animal Behavior in the Smart Vivarium [8]

The article describes the computer vision and machine learning technology behind the Smart Vivarium. The smart Vivarium is the new way of animal behaviour monitoring and early detection and prevention of illnesses. It is suitable for mice, rats, rabbits and other small mammals. According to the paper, automated behaviour monitoring improves the animal care and efficiency of the data collection and simplifies the detection of the abnormal behaviour.

Small Birds

Timing of site fixation upon the wintering grounds in sparrows [9]

This paper focused on the process of site fixation during the winter seasons and its impact on bird population. The period of time for fixation usually is placed by fall to February. They also separated the birds into two groups, adults and sub adults, and examined the results. The data showed time delay on fixation could repopulate regions at the end.

Analysis of droppings to describe diets of small birds [10]

They searched for the method to examine stomach contents of small birds without killing endangered species for the study purpose. So, they decided to track the numbers of droppings of small birds and showed how effective this method was.

A syllabus of training methods and resources for monitoring landbirds [11]

In the document a guide to courses to teach the methods for monitoring landbirds is introduced. First, locating and laying out plots, nest searching methods and nest monitoring methods. It all contains explicit procedures and evaluation, so it could be useful when bringing that into the experiment and making use of it.

Monitoring bird populations by point counts [12]
It shows the need for standards and their applications to point counts methodology of birds. It highlights its significance of counting buds with recent concern over declining tendency of migratory landbirds. In addition, it explains the benefits of counting buds in terms of precision and accuracy of the estimation.

Rodents

Monitoring techniques for vertebrate pests Mice [13]
The paper summarises many mouse abundance and impact monitoring techniques used for mice. Techniques such as bait-take, crop damage and trap success. These techniques all have their own advantages and disadvantages. It also includes the materials and formulas needed for the monitoring.
Advantages: simple, inexpensive and can be incorporated into existing economical management. Disadvantages: labour intensive, expensive and unreliable.

Camera Trapping: A Contemporary Approach to Monitoring Invasive Rodents in High Conservation Priority Ecosystems [14]
The paper discusses the techniques of monitoring trap-adverse rodents in high conservation districts. The usage of multiple horizontally mounted cameras made it possible to get precise data on the species that roamed there.
Advantages: It is negating target and non-target impacts of live trapping and animal welfare
Disadvantages: To calculate the estimated density of population, you have to identify individual animals.

An Improved Technique for Monitoring the Drinking Behaviour of mice [15]
This article describes the technique for monitoring the drinking behaviour of mice. They used an electronic lick counting procedure to collect the data for the alcohol consumption. The output was a square wave signal with a maximum frequency of 20 per second.

Advantages: Availability of microcomputers allows large scale system, usage of normal cages
Disadvantages: cannot distinguish the consumption for calorie motivation or pharmacological effects

Fish

Effective monitoring of freshwater fish [16]

This paper deals with the different methods of monitoring freshwater fish. It has an overview of all the different *monitoring techniques* in correlation to the **type of fish** and the **kind of results** the monitoring program should produce. According to the article the most important aspects to discuss before starting to monitor are the **aim(s):**

"**(a)** what should be monitored and how;
(b) how to allocate effort within time and across sites;
(c) establish criteria for data reliability; and
(d) identify practical constraints." (Article, Chapter 9 Conclusion)

Development and intercalibration of methods in nordic freshwater fish monitoring [17]

The paper at hand focuses on monitoring nordic freshwater fish by making use of so-called multi-layered *gill-nets*. Each layer has a specific **mesh size**, therefore it only catches fish with a specific size. Then the **amount** of fish caught with every net can be **documented** and **evaluated**. The article also mentions the inaccuracy of **age determination** of different fish and compares the *deviations of estimates* from different experts and different methods.

Fish sizing and monitoring using stereo image analysis system applied to fish farming [18]

The paper explains the principles of determining the **length** of **fish** using **2** precisely placed and calibrated **cameras**. The cameras both record the fish and by making use of the different angles, a **computer** can **calculate** the **length** of the fish with up to 2 mm accuracy. If a **powerful** system is used at a high *sampling rate*, also the **movement** and **position** of all fish that are currently in the frame. This could also help monitor *fish farms* and the **behaviour** (e.g. eating) of the fish.

Large Birds

Monitoring important bird areas in africa [19]

This article is about making monitoring of species of birds more effective on a large scale.
They describe how monitoring can be done more efficiently in rain forests and other difficult areas where they want to measure the amount of different species of birds. This is necessary because they see that the amount of birds is decreasing or changing without knowing which species are decreasing and why.

Pigs

Monitoring wild pig populations: a review of methods [20]

This paper describes available methods of pig monitoring and weighs pros and cons of each method provided. The main criteria that are searched for are: 1) needs to be practical in the field, 2) needs to be data sensitive to notice any abnormalities, 3) no assumptions if it can be checked with the method, and 4) needs ability to make statistical comparisons. According to the paper, the key to successful monitoring is to use reliable statistical design concepts, such as habitat or area of the monitored place etc.

Chapter 2: Identification of General Problems and Challenges

This chapter contains the most occurring problems and challenges that can be found in the publications of the previous chapter.

Finding animal tracks

Gathering tracks is time consuming especially if there's a wide area to monitor. The weather can also be adverse and complicated for the research of tracks. If it snows or rains the tracks can be modified or disappear.

Data interpretation

When using sensors instead of manually gathered data, this can produce mass data. Which sounds good, but also needs a lot of care to properly interpret this data, taking into account the when and where of every piece of data collected, understanding what the sensordata means and if any data should be filtered/changed/left out because of ageing/malfunctioning equipment or other reasons. Finally, conclusions have to be drawn from the corrected data to explain what is happening with the animal population and what actions should be taken.[1]

Human labour

Many methods of animal tracking require humans to go out there and locate animals, and process the data manually. This leaves room for human error, requires participation from volunteers or money from professionals.[2] Moreover, this process can be really time consuming and deliver little data. This then requires more organisational work.

Lack of Research equipment/resources

Finding relevant research equipment is required for each species. Sensors are not always cheap and most need maintenance over time. Tools like binoculars are not always available especially in poorer countries, despite them having a large biodiversity and thus being more important. Some research is also prolonged over time, and the expenses keep rising.

Lack of framework/previous problems

Wild animals living in harmonic natural environments usually are not the problem. Taking those inhabitants into concerns and disturbing their area for research purposes can potentially cause general ecosystem problems without noticing. In addition, It will be challenging to deal with species like endangered animals with lack of background knowledge.

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[1] Mankin, R.W. *et al.* (2011) *Oxford Academic*. American Entomologist. Available at: https://academic.oup.com/ae/article/57/1/30/2462094?login=true (Accessed: November 24, 2022).

[2] Braschler, B. (2009) *Successfully Implementing a Citizen-Scientist Approach to Insect Monitoring in a Resource-poor Country*, *Oxford Academic*. BioScience. Available at: https://academic.oup.com/bioscience/article/59/2/103/228112?login=true(Accessed: November 24, 2022).

Destructive research

Catching animals and partially also having to harm them or disturb their natural environment in order to create a proper study, can have negative effects on the animal stock. This defeats the purpose of research to save the environment to a certain extent.

Technical Sensor difficulties

Some sensors need to be accurate and precisely set in order to properly produce the output wanted. They need to be accurately adjusted depending on the environment, the species, distance from the animal etc. Technology for these sensors is not always there yet and takes time and money to develop. Furthermore, sensors require energy to sense and communicate their findings.

Inaccurate sensors

Inaccurate sensors can result in inaccurate data. When measuring the size of animals, for example, by using camera sensors, slight inaccuracies can distort the whole result of the program. Sensors can age, be knocked over by animals or be covered by snow.

Locating animals

Finding the exact location of a certain type of animal in the wild can be a difficult task. In order to monitor the animals, they have to be picked up by the sensor or a human. The right sensor placement is essential for the data. The usage of bait also doesn't guarantee that the animals will come.

Chapter 3: Identification of Relevant Problems

In this chapter, five most relevant wildlife problems will be introduced with their main cause and their negative effects on the ecosystem.

1. Light pollution affecting insects[3]
With increasing urbanisation, artificial lights affect insects. Turning the light on during night time impacts their natural light-cycle, which throws off their hunting skills and mating processes. In addition, lack of natural lighting can also lead the insects to lose their path. These effects can eventually kill them. This changes food chain balance by giving more benefits to particular species to hunt and potentially constraining their mates, resulting in drastic changes in ecosystems. This is a problem because insects are necessary for farmers to grow enough crops into urban areas. It is crucial to find the optimal way to reduce artificial lights, especially at night.

2. Grasshopper Plagues
It is a major problem in areas where there is a lot of drought during the summer seasons, especially in North America, Africa and Australia. Grasshoppers are a major problem there, because the drought is an ideal place for the grasshoppers to hatch their eggs. They cover many roads and they can eat about 800 acres a day if the group is large enough. This gives a lot of farmers nightmares, because it is the food that they are growing on their acres that these grasshoppers want. Especially in Africa, where it is already hard to grow food because of the heat and drought and there are a lot of hungry children, it is a major problem. So how is it possible to prevent a baby boom of grasshoppers, to keep them from eating the food growing on acres, or to detect such a big group from earlier on so that farmers can set up their defence against grasshoppers?

3. Crop Destruction by Wireworms
Agriotes Lineatus (Wireworms) have been known to be severely destructive to arable crops in the recent years all around The Netherlands. In general, wire worms are after carbon dioxide that arable crops release. The main habitat of theirs is underground in the soil. They destroy the root of the plant and no chemical has much effect on them. Current approach of The Netherlands is good at detecting some worms but it doesn't predict the damage caused by them. This is the main reason why this needs to be taken care of.

4. Bees under attack
A local farmer said that his bees are frequently attacked by Asian hornets, wasps, and varroa mites. He already tried different solutions but nothing worked as expected, so he’s still looking for a better solution. Maybe it is possible to find something (light or sound) that

[3] Gaston, K. J., Bennie, J., Davies, T. W. & Hopkins, J. (2013, 8 april). The ecological impacts of nighttime light pollution: a mechanistic appraisal. https://onlinelibrary.wiley.co. Accessed on 22 december 22AD, https://onlinelibrary.wiley.com/doi/full/10.1111/brv.12036

repulses these types of hunters. Our current amount of knowledge about these types of hunters is little, but the beekeeper is really open to help us gather more information in case we are going to choose to work on this problem. This problem is of course important because bee’s are one of the most important animals in the ecosystem, as they help pollinate a large part of the plant world.

5. Bats[4]

Bat species throughout the Netherlands have greatly suffered from the urbanisation of the western world. With less remote, cold cave-like places for them to rest and reside in, and less silent places for them to hunt insects undisturbed at night, the number of bats has decreased. Bats take up a semi-important role in the ecosystem as a night predator and as such, there should be efforts to preserve this animal.

[4] Vleermuizen algemeen. (n.d.). De Zoogdiervereniging. https://www.zoogdiervereniging.nl/zoogdiersoorten/vleermuizen-algemeen

Chapter 4: Problem Selection and Motivation

The most relevant problem that is selected from the five problems of the previous chapter is written below. It contains an extensive explanation of the problem and the motivation of why this problem is chosen.

The effects of pollution on insects

One outcome of industrialisation and climate change is the decrease of the insect population through light, air, sound and other kinds of pollution.

Light pollution attracts animals, killing them immediately or leading them off their path confused and likely to die. Light pollution exists in 4 types: through the sky(light emitted by cities goes into the sky and partially returns), glare(extremely bright lights), clutter(large groups of bright lights), light trespass(light that reaches places where it is not intended.)
(https://education.nationalgeographic.org/resource/light-pollution)
Below is a graph that in more detail describes the way insects' behaviour is affected by light.

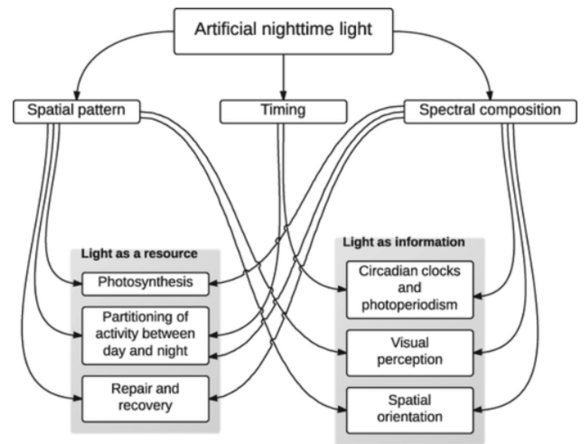

Figure 1[5]
(circadian clock is an internal clock that tracks night and day, photoperiodism means using light to determine what season it is).

Insect behaviour is also influenced by sound (and vibration) pollution. Some types of insects use sounds or vibrations through the ground to communicate with each other. For example with ants, this throws off the organisation of the nest. But more commonly, sounds mess with mating calls of insects. Both lead to a decreased chance of survival for the species. [6]Lastly,

[5] Gaston, K. J., Bennie, J., Davies, T. W. & Hopkins, J. (2013, 8 april). *The ecological impacts of nighttime light pollution: a mechanistic appraisal*. https://onlinelibrary.wiley.co. Accessed on 22 december 22AD, https://onlinelibrary.wiley.com/doi/full/10.1111/brv.12036
[6] Cammaert, M.-C. & Cammaerts, D. (z.d.). *Impact of environmental noise on insects physiology and ethology - A study on ants as models*. https://www.oatext.com/. Accessed on 22 december 22AD, https://www.oatext.com/impact-of-environmental-noise-on-insects-physiology-and-ethology-a-study-on-ants-as-models.php

modern urbanisation has also polluted air and water. Cars and factories emit gases and other substances that pollute air and water. Much like humans, insects survive better with clean water, and the biological chemical processes in their bodies function better if the air is normal (with a standard gas composition and temperature).

Importance:
This decrease in population has great effects on ecosystems, food chains and agriculture. Declining insect populations can reduce the ecosystem services provided by beneficial bugs, such as pollination of agricultural crops, and biological waste disposal. The consequences of the decreasing insect population are a critical factor in modern society. Humanity already has problems with extreme weather phenomena destroying crops and having to deal with more crop shortfalls because there are no insects to pollinate flowers is an unnecessary additional burden. The influence of insects on food chains and ecosystems is another aspect, which shows the importance of a balanced amount of insects in nature. This project is dedicated to research how different kinds of insects respond to specific lighting / sound / air conditions, which can provide information to form guidelines on how to minimise harm to wild insects.

Chapter 5: Potential Solutions

This chapter contains the potential solutions for the problem chosen in chapter four with their corresponding explanations.

Common design of the solutions

The solutions proposed below are meant to monitor the wildlife and discover which gases, sound or light etc. could somehow be adjusted in the cities to stop affecting insects. With the exception of solution 5, the plan is to use an installation with boxes equipped with a camera that gets triggered by a motion sensor. The images the camera takes are processed by an AI that can detect and distinguish different kinds of insects. The amount of insects is then used to determine the attractiveness of certain different attractors to different kinds of insects to find the least harmful one. The installation will be set up in a place with many insects to improve the quality of the collected data. For example log piles, overgrown areas, compost heaps, ponds or wildflowers.[7]Insects are attracted to smells and colours that indicate aspects of their ideal environment (Eg. bees from colours and smells from flowers// flies from strong smell of organic elements[8] so depending on the chosen environment the solution might attract different insect species.

[1]Determine harmful light wavelengths

Using sample lights to see which insects are attracted to certain types of wavelengths of light. This solution has been explored by other researchers, but is interesting regardless. This solution involves the use of different boxes, with each simulating a different light environment, changing the light in colour, brightness or type. The installation would require a device that emits light of varying wavelengths & spatial patterns at varying timings. The setup would have sensors to detect the presence of and determine the type of insect. This solution would provide information that can inform city designers of what wavelengths of light are harmful to insects.

[2]Determine influential gases

This solution uses a sample of smells to determine gases that influence insects. First, set up the monitoring box with different kinds of chemical attractants[9] to gather insects. The setup would also release potentially harmful gases that are often emitted by cities. The smells can contain floral, fruity, or any other mixture of artificial scents. Examine the insects' movement tendency and analyse the result with different combinations of smells. This solution would give information that can be used to either come up with a plan to reduce harmful smells, or a plan that uses smells to influence insect behaviour in a way that protects them.

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[7] *how-to-attract-insects-garden*. (z.d.). Kew. Accessed on 22 December 22AD, https://www.kew.org/read-and-watch/how-to-attract-insects-garden.

[8] http://www.rainews.it/archivio-rainews/articoli/Di-tutto-punto-come-evitare-zanzare-e-co-757aa282-4124-4585-a8b0-580b08a39206.html

[9] Jacobson, M. & Beroza, M. (1964, augustus). *INSECT ATTRACTANTS on JSTOR*. Accessed on 20 December 22AD, https://www.jstor.org/stable/24931593

[3]Determine harmful sounds
Use sounds and vibration to see which insects are attracted. This solution also involves luring the insects to the installation using chemical attractants. The installation would play recorded noises and vibrations typically produced by cities(e.g. Traffic noises, construction work, sirens), as well as a spectrum of other sound & vibration frequencies. When the insects are close to the setup, use sensors to examine the insects behaviour, determine differences in behaviour depending on sounds/vibrations, and compare it to their normal behaviour patterns. This solution would provide information on frequencies that bother insects, that could help in formulating a plan to eliminate/reduce the amount of these frequencies that reach nature.

[4]Determine influence of temperature
This solution monitors the amount of insects attracted to different temperatures. The setup of this solution will include installing a box outside of the city with as few artificial heat emitters as possible. The box will contain a heater that can differ from temperature, a camera and an insect sensor. Every night, the heater in the box will be set to a different temperature. The sensor will then activate the camera that will make a picture of the insects present in the box. When analysing these pictures, the different types of species and amount of insects that are attracted to certain temperatures can be determined.[10]

[5]Light pollution app
Contrary to the solutions so far, this solution makes use of citizens. The citizens can download an app that is used to track interactions between insects and artificial light. Whenever a citizen would see an insect attracted to artificial light, the person would enter information on the light type(colour, intensity), the layout of the area(proximity to nature) and the insect type, which would be sent to the server with a database. Additionally, they would take a picture of the moment, that can then be used to verify user-entered information. The app would also record time, temperature, and GPS location for each entry to the database. This solution would provide extensive information on problem situations, where insects are actually affected by light, which can be used to make a plan to avoid such situations in the future. This system would not be able to track effects of light pollution in lesser populated areas, which is where the majority of the problem(light pollution reflected back of the sky) occurs.

Potential solution expansion
While detecting the number of insects and the species with the trap(in solutions 1,2,3 & 4), regardless of the detection method(sound, smell, light, temperature), there is the ambitious goal to add more sensors that register the humidity and outside temperature every time a photo is taken. This would provide more information for analysis, and allow for more complex pattern recognition.

[10] *Insect Disturbance and Climate Change | Climate Change Resource Center*. (n.d.-b). https://www.fs.usda.gov/ccrc/topics/insect-disturbance-and-climate-change

Chapter 6: Solution Selection

This chapter explains the chosen solution between the above mentioned ones. More in detail, it gets through the design of the final solution.

Determine harmful light wavelengths

Using sample lights to see which insects are attracted to certain wavelengths of light.
This solution has been explored by other researchers, but is interesting regardless. Below is a figure of the solution:

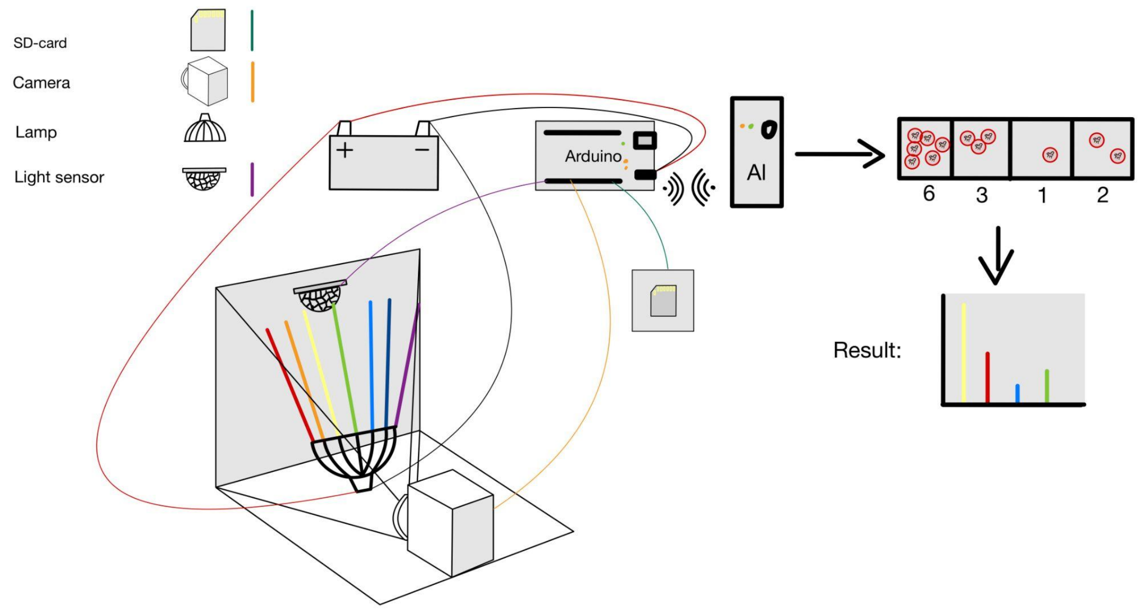

Figure 2

The solution consists of an installation in the wild that will communicate with a server. This installation will activate at night and emit a wavelength of light. This will change every night. The insects that are attracted to these lights will be detected with a photoresistor, and when that is triggered, the camera will take a picture and it will be sent to the server, along with the time, location, current humidity and current temperature. The server will then determine what insect species was photographed and add a line to the database with all the info. (see figure 2)

When these results are compared with each other, a conclusion can be made about the influence of the wavelength of light to the attraction of insects. By studying the behaviour of insects under certain conditions it is possible to better predict the difference a change in street lighting would make. By sharing this information with a local government, there is a chance of making a difference.

Chapter 7: Methodology

This chapter discusses a few points: if the requirements of a smart environment are met with the chosen solution, the calibration of the sensors and the collected data. There is also a list added of the equipment needed for the solution and of the time planning. Lastly the possible expansion of the basic plan to an ambitious plan is included.

Smart environment

The solution consists of several installations in the wild that will communicate with a server. These installations will activate at night and emit light with a certain wavelength. The wavelength will change every night. The insects that are attracted to these lights will be detected with a photoresistor, and when that is triggered, the camera will take a picture and it will be sent to the server, along with the time, location, current humidity and current temperature. The server will then determine what insect species was photographed and add a line to the database with all the info. (see figure 2)

The solution qualifies as a smart environment as it meets the five criteria of smart environments. The system is able to collect and process data on its own, and has no user-interface other than the data collected from the sensors, this will be processed by an AI in the server after it is wirelessly sent from Arduino. This data will include humidity and temperature sensors, making it context aware. The system will be able to deal with different inputs (different types of photos) through our AI. Therefore our solution requiring big data works does qualify as a smart environment.

Equipment:

Equipment for each box (1 box)

Equipment we have access to

1 SHT20 digital temperature & humidity sensor
1 Photoresistor
1 Power Source
1 Encasing Material

Order List:

3 ESP32-CAM
3 ESP32-CAM-MB Micro USB to Serial Port (shield to program ESP32-CAM)
3 4GB micro sd Card
1 Strong, dimmable RGB LED

General equipment:

- AI
- computer(server)

Because the insects are really small and the probability that the sensor is not accurate enough to detect them is high, paying attention to determining the best sensor for this use case and calibrating it correctly is essential. The humidity and temperature sensor will also have to be adjusted so they output on a scale that makes sense for an outdoor environment.
The equipment will not be used in a controlled environment, so that means our AI will have to be able to deal with pictures taken at different times of day with different weather and light. The box will be standing outside in a dark place with as little other artificial lights surrounding it as possible, so as to not influence our results. There is no special casing needed for the box itself, but the electronics would need a waterproof casing.

The photoresistor, mounted opposite to the light in the box, can, if calibrated accurately, detect minimal changes in light intensity (if an insect is between the sensor and the light source) and then trigger the camera. The picture that is taken will then be sent to the server via the integrated wifi, which can then identify the amount and type of insects. This data will be collected in a dataspace. The photo itself can be discarded. The data that is collected will give information about the amount and types of insects that are attracted to different wavelengths of lights. A different wavelength of light is on every night, with the arduino determining which one, based on what light wavelength it does not have sufficient information about yet.

When these results are compared with each other, a conclusion can be made about the influence of the wavelength of different light types to the attraction of insects. By studying the behaviour of insects under certain conditions it is possible to better predict the difference a change in street lighting would make. By sharing this information with a local government, there is a chance of making a difference.

Ambitious vs Basic

When the basic functionality of the project is given, it can be expanded by:
-Improving the AI detection methods to better track the insects instead of just processing a picture.
-Incorporating the humidity and temperature sensor.
-Expanding the list of light types.
-Improving the quality of the data processing(taking more data e.g. humidity and temperature in account, improve the efficiency of the code)

Weekly time plan

Date	General Tasks/ scenarios	Assigned tasks
16-22 Dec	Research on equipment needed: 1. Battery (later) 2. Casing (later) 3. Light source 4. Storage chip 5. Insect sensor 6. Camera 7. Humidity sensor 8. Temperature sensor Decide what to use, and all the components to buy.(buy them)	Understand equipment and know how to use it Arnoud - Light Elia - Storage Oskar - Camera Nina - Humidity Sigrid - Temperature Aidana - Casing material Sven - Battery
23 Dec -8 Jan	Messing around with design, electronics programming, understand and have your own part done by the end of	Arnoud- programming

Date	General Tasks/ scenarios	Assigned tasks
(Holiday weeks)	the holidays. Keep in touch with everyone about upgrades and development, to know what's going on and adapt to the general plan and new problems.	Elia-arduino, programming Oskar- programming, design (help) Nina-documentation Sigrid-arduino Aidana-documentation, design Sven-arduino
9-13 Jan	Assemble everything and make tests.	
14-20 Jan	Fail the week before and adjust mistakes, calibrate better. If everything is fine, skip this and look at the next week	
20-24 Jan	Finalise the reports by analysing every data collected from the sensor by AI. Add the humidity and temperature sensor(ambitious).	
24-27 Jan (Demo days)	Test if everything works fine, make a simulation or sample model for the street light.	

Division of responsibilities:
Making/designing casing for the box: Aidana
Documentation: Nina
AI: Arnoud
Camerachip (setting up connection of wifi to computer): Sigrid
Data processing: Elia
Hardware(wiring electronics: sensors & actuators): Oskar

Daily Time plan (revised)

DATE	General goals	Assigned tasks
Thu, Jan 19	Preparing for the first prototype presentation	Arnoud - AI research Eila- processing code Oskar- Arduino / sensor Aidana- wood cutting Nina- processing code Sigrid- Arduino
Fri, Jan 20	Feedback session	
Mon, Jan 23	Short meeting	
Tue, Jan 24	Assembling everything together and start monitoring	Arnoud - working on AI Eila- Processing code Oskar- sensors and soldering Aidana- painting and fixing holes Nina- fixing document and helping with casing Sigrid- sensors and soldering
Wed, Jan 25	Finishing the processing data visualisation and analysing the pictures Finishing the final report	
Thu, Jan 26	Preparing for Demo Day. Final check on prototype	
Fri, Jan 27	Demo Day	

Chapter 8: Validation

This chapter validates the results through tests and a scientific evaluation process.

To know whether the solution that was chosen works or not, it had to be tested on a small scale. The validation of the setup has been split in four: The camera-sensor activation, the AI image processing, the data processing and the connection between the different parts.

Camera-sensor activation:
For all the sensors and actuators, the ESP8266 board is used as a core chip. 9 LDRs and 10K of resistor for each LDRs are connected to the analog pins of the board in order. The input values, the changes in light intensity caused by insects' movements, trigger the ESP32-CAM which is also attached to the ESP8266 and stays in sleep mode in usual time. The ESP32-CAM board works with the micro SD card and stores the pictures taken. It is connected to the serial port through the ESP32-CAM-MB, the Micro USB doing a job of shielding. At first the box sensors were tested inside with a fake insect. A small insect was printed out and attached to a stick. The sensors inside of the box sensed the fake insect and triggered the camera to make a picture. This worked reliably.

When everything was working as planned, the setup was tested with real insects. The box (with the required light source and sensors) was placed outside in a garden (see figure 3.1 and 3.2). It was made sure that the surrounding buildings turned their lights off to 1) attract more insects to the setup rather than the surrounding lights and as such, get more (reliable) data and 2)establish environmental factors to replicate in future experiments. During the night, there was one type of wavelength emitted by the light.
The camera, besides just making pictures when it sensed an insect, also made a picture every eight minutes. This approach was applied to check the sensors and camera. If the pictures that were taken on the eight minute timer contained insects, but there were no pictures taken by the sensors, it would indicate that the sensors or camera were faulty. Next to this, the setup was also tested manually before and after the experiment, with positive results(pictures were taken when the LDR sensors were triggered).

After conducting the test for several days and analysing the pictures, there were few results. There were no pictures made by the sensors, the pictures that were made were activated by the eighth minute timer. These contained no insects. Possible explanations for this are a faulty sensor-camera setup, ineffective bait (light did not attract insects) or the lack of insects in the environment. As the equipment was tested and the light was quite bright, the lack of results is likely due to the absence of insects. An important element of the presence of insects is the temperature. There are more insects active during the night if the temperatures are high. The days that the box was monitoring insects had low temperatures during the night, it was around -1℃. There were likely little to no active insects the sensors could pick up.

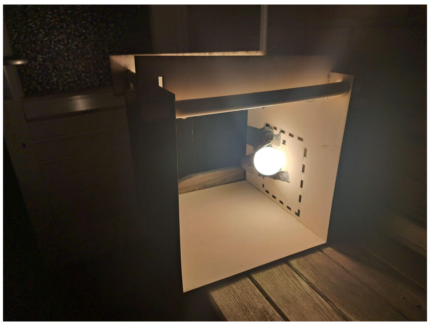

Figure 3.1

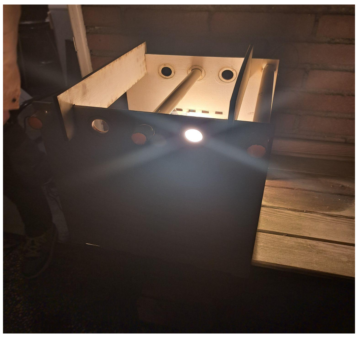

Figure 3.2

AI Image processing:
Images received from the camera should be processed by an AI and return the insects in the picture. Ideal for this would be an object detection & object classification CNN. The AI used is a quite basic CNN(convolutional neural network) set up in python using the tensorflow library. An attempt was made to make a dataset for insects based on different existing datasets found online but this proved to not be effective, as the AI was only slightly better than random chance with this dataset(with only 5 insect categories). Because of this, it was decided to continue with a general purpose dataset. The concrete workings of the image processing part were validated by the accuracy returned by the program(51% when using images from the same dataset(that were kept apart from training data), and by the 1 picture test, printing the AI's prediction of a single picture. However, for practical use the accuracy and detection methods would have to be improved.

Data Processing:
The data that is processed by the AI is visualised in Processing. It offers a user-interface that shows a graph displaying the amount of insects attracted to a type of wavelength. The interval of the monitoring and wavelength and the intensity of the light can both be manipulated with the use of sliders in the program. To test the input of the data in the graph, multiple randomly generated values for the date, insects and wavelength were given to Processing. The values were then displayed as a dot in the graph with a specific size and location as expected from the data. The size of the dot is determined by the amount of insects monitored.

Connection between parts:
The solution relies on connecting the camera-sensor setup and the central processing server with the use of Bluetooth. In practice, data-corruption during this process proved to be an issue. A manual, non-autonomous alternative for this was using a micro SD card instead. The pictures that were taken from the camera-sensor setup are stored on the micro SD card of the ESP32-CAM. The micro SD card is used to insert the pictures in the central processing server. The AI processes the images and converts the data into a csv file. The csv file is then sent to Processing, which displays the data in the graph. The functionality of this is validated by a datapoint showing up in the Processing graph whenever a photo is analysed with the AI.

Chapter 9: Results and Conclusion

This chapter contains the results, findings and conclusion of the project.

There were hardly any results provided by the validation process of the box. The only pictures that were taken by the camera were caused by the eight minute timer, and not by the sensors placed inside of the box. There is not much that can be concluded from these pictures, only that the camera-sensor setup works and that there are no insects active with low temperatures during the night.

This leads to the conclusion that the box should hypothetically be able to monitor insects, if the following adjustments are made:

1)The photos from the Micro SD are transferred through bluetooth to the central processing server. The hardware for this is already in place.

2)A quality dataset for insects is made. Currently the AI is using a general use dataset.

3)The AI is upgraded to not only do object classification but also object identification, and is calibrated to deliver good results(with improved preprocessing and training).

4) Measurements are made over a longer span of time, including results in other seasons.

The sensors detect the fake insect when tested inside and the camera makes pictures when needed. To really test whether the box works outside in a natural environment, the days of monitoring should have nights with high temperatures. Then there will be active insects that the sensors can detect and activate the camera.

The ambitious plan as mentioned above at chapter 7 was not fully realised on time.

-Since there was no valid dataset of the pictures taken that the insect presented while monitoring, achieving the advanced-level of AI training seemed unfeasible.

-The system covers for all light types, using a dimmable rgb LED. It can emit all colours and intensities of light required.

-The system also has ambitious data processing/visualisation software, with scalable axes and filters. Although there was no data to represent, the software would be able to display necessary types of data if it were there.

-Incorporating the humidity and temperature sensor were not implemented due to time constraints.

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