UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

Group 2

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Chapter 0: Introduction

In the field of Wildlife monitoring, developments of insect populations have been a subject of concern for some time, with several publications chronicling their dramatic decline [1]. More recently however, focus has shifted to highlight some of the complexities to this, as the consensus regarding the extent of this decline is not entirely clear [2]. In our project group, consisting of Bas Liebe, Eris Vornhecke, Andrei-Claudiu Iarca, Maaike van Lochem, Fernando Nicolas González Rico, and Candela Cimadevilla González, we decided to take on a wildlife monitoring issue such as this one, through the development of a suitable smart-environments solution. The topic of insect monitoring was identified from a larger selection of subjects outlined in our literature search, which encompassed topics from the societal impacts of wildlife monitoring and effectiveness of certain methodologies, to specific applications such as wildlife corridors and lobster population management. Through brainstorming such various categories, and assessing them for feasibility given our available tools, budget, and time frame, we arrived at insect monitoring, where the issue of population decline struck us as relevant. Herein, the aforementioned inconsistency in population decline observations made us investigate potential solutions that would allow for much needed improved and accessible monitoring, to eliminate uncertainties, and allow the development of a better understanding of the scale of insect population developments. Furthermore, we identified the issue of invasive monitoring methods in which the insects would come to harm or be killed by monitoring systems, something we wanted to avoid. We developed several possible concepts for smart insect monitoring and assessed these for relevance, achievability, ease of implementation, and potential for expansion and ultimately arrived at the concept of a pitfall trap. We also settled on this concept for reasons of modularity and low costs, further increasing the potential for large scale deployment. A traditional pitfall trap typically involves a catchment pit that ground insects may wander into and be counted. Our concept (further described in the methodology section) would present an automated alternative to traditional pitfall traps, which require manual observation and insect release, making them less efficient than our automated solution. Automating this process would be more widely deployable and consequently allow for a larger scale of monitoring. The trap itself was chosen as it would not kill insect in its catchment method, but rather temporarily collect and count them before releasing them. The automation would consist of a sensor detecting the insect as it is caught by the trap, and subsequently trigger the release mechanism, raising the ground of the pit to surface level to release the insect. Recorded insect numbers would then be sent off to a central server where they can be further studied and analysed. More details on our development process and methodology can be found in the sections below.

Chapter 1: Literature Review

Find 20 meaningful publications on the general subject of wildlife monitoring. Make a summary of each publication.

You should add references properly, following the IEEE style.

[3]**Large scale wildlife monitoring studies: statistical methods for design and analysis**
This article discussed a number of different models that can be used to estimate population consistency and growth of animals. In particular, it pointed out some general flaws with common methods used to model populations, while offering better alternatives for a number of different animals, namely fish and salamanders as examples.

[4]**Rivierkreeften, een oprukkend probleem?**
This article, while being slightly dated, mentioned a problem which is still relevant, if not more relevant nowadays: the invasion of exotic American lobsters in the Netherlands. Ever since these were introduced in 1968, American lobsters have shown to be damaging to Dutch underwater plant life and generally have a negative influence on the biodiversity in Dutch ditches, lakes and channels.

[5]**Roadkill risk and population vulnerability in European birds and mammals**
This article illustrated the threats roads pose to wildlife in Europe through a number of facts and figures. It explains how smaller mammals and birds most often fall victim to road incidents. Among other factors, it aims to explain the reasons why some animals are more commonly targeted than others and tries to offer a number of different solutions.

[6]**Animal movements in fire-prone landscapes:**
Satellite images are able to track the area affected by a fire, but the damage is not equal throughout all the surfaces. In order to identify how the severity of this damage varies in different locations other methods of monitoring need to be used. These methods include: radio tracking to determine variation in the home-range size of certain bird species, fluorescent pigment to track fine-scale gecko movements and quantify the influence of grass height, data sets where individual animals are tagged and released to allow subsequent identification and the use of accelerometers to identify the activity patterns depending on the area.

[7]**SWWS: A Smart Wildlife Warning Sign System:**
In the USA big mammals crossing the road and getting run over is a considerable problem. In order to solve this the SWWS was designed. It consists of an infrared and microwave radar sensor array that activates blinking LEDs when an animal is nearby, warning the drivers. During daylight the sensors also triggers a camera that takes a picture of the animal, helping monitor local wildlife as well as preventing accidents.

[8]**Dutch authorities allow firing of paintballs to scare ‘too tame’ wolves.**

There is a population of wolves in the Veluwe park that has grown accustomed to humans. Because of this they no longer run away when they see people, and this can be dangerous. To solve this problem the authorities have given permission to fire paintballs to the wolves.

[9] **Monitoring of Wildlife Populations**
The first topic this publication discusses is the reasons why humans practice wildlife population monitoring and its importance, an example being the observation of endangered species in order to study their progress and recovery. The second paragraph explains ways in which the population of animal species can be looked at, such as radars, thermal cameras and looking for their tracks, or even attaching monitoring devices, like collars or leg bands. However, there are cases in which these devices harm the animals which is not ideal.
One of these is presented in the article, and it states that it is necessary to mark individual penguins within a colony to be able to monitor wild penguin populations and despite the fact that this is important for the data collection, the welfare of the banded penguins can be compromised when traditional metal bands are attached to them, while also affecting their population. Studies show that marked penguins have a 16% higher mortality rate and produce 39% less chicks.

[10] **Methods for wildlife monitoring in tropical forests: Comparing human observations, camera traps, and passive acoustic sensors**
This article presents the three main methods of monitoring wildlife in tropical forests, which are human observations, camera traps and passive acoustic sensors. While forests like these are widely inhabited by substantial amounts of different animal species, they consist of complex nature that is particularly challenging to work around for scientists that study this environment. Because of the low and variable detection probability, there is a risk of bias toward certain spots and time spans where and when monitoring is more accessible. Another problem with these methods is the limitation of resources.
Every method comes with its own pros and cons. Live human observations are usually done for general data about large and easily spottable animals. This procedure is the oldest one and is quickly becoming increasingly inefficient compared to newer technology, but nevertheless it is still put into practice due to the low costs and insight it implies. The obvious downsides to human observation are the lack of precise data and the extremely limited vision.
Camera traps are proficient in spotting any kind of animal species and are accurate in the data they provide, which is why they are often being used in wildlife monitoring. Despite that, their range of action is limited to 10-20 meters, which calls for various inconveniences. Installing them in randomized locations takes quite a lot of effort since they need carefulness in terms of positioning and maintenance, not to mention that the cost of these machines is on the higher end of the spectrum.
Passive acoustic sensors (PAM) may be the most efficient mechanism for monitoring wildlife. Thanks to their extensive range of vision and intelligent software, they are suited for almost any kind of information gathering in this field. But of course, with such high-end technology comes a large amount of money and limitations in other ways. PAMs are expensive and require highly trained technicians, while also needing high computing power, which means that the investments for these devices are excessively pricey.

[11] **A Technical Guide for Monitoring Wildlife Habitat**
This article describes a few methods to monitor the habitat of forest wildlife. Different types of monitoring are explained as well as the definition of what a habitat exactly is. Also, the key concepts of how to set up habitat monitoring are explained.

[12] **The Basics of Using Remote Cameras to Monitor Wildlife**
This article describes the basics of how to use a remote camera to monitor wildlife. Different options, as well as camera types and advantages and disadvantages are explained.

[13] **A portable low-cost remote videography system for monitoring wildlife**
This article describes how a remote videography system for monitoring wildlife works. Materials and methods to build such cameras are explained as well as what you can do with them.

[14] **The role of soil community biodiversity in insect biodiversity**
In this article, the relation between insect biodiversity and plant biodiversity was studied and analysed. In conclusion, both have an extensive influence on one another. This means that biodiversity loss in one community may lead to similar loss in the other, though this is highly species and community dependent. However, many other factors, such as fungi and pathogens, also significantly determine plant diversity. Additionally, it was mentioned that there are very few good methods of tracking below-ground insects.

[15] **Wireless Sensor Network Deployment for Monitoring Wildlife Passages**
This paper discusses the tracking of animal movement using a network of sensors. The sensors are placed in remote locations in order to make safe ways for animals to cross human infrastructure. A combination of sensors is used such as cameras and infrared in order to obtain the most information. This specifically aims at making it easier to cross the road eliminating the amount of roadkill's. The usage is implemented to make sure the correct behaviour is being implemented.

[16]**Framework for Intelligent Wildlife Monitoring**
This paper talks about a network of discrete cameras placed amongst remote places. It shows effective ways on how the environment develops including flora and fauna. The data can be successfully stored and used for future applications.

[17] **Lead toxicity to wildlife: Derivation of a critical blood concentration for wildlife monitoring based on literature data**
This article talks about lead poisoning due to high levels of it in soil. Random birds we taking to study and revealed to have high levels of poisoning. Up to 2% where in the normal levels of lead. Studies were held mostly on birds because it turned out they were the biggest affected by it.

[18] **Reasons Why You Shouldn't Feed Wildlife**

Feeding wild animals can lead to them losing the ability to find their own food and an increased density of population which makes diseases spread faster. It also makes animals lose their fear to humans and appear aggressive towards people which sometimes causes them to be put down.

[19]**Benefits and challenges of collaborating with volunteers: Examples from National Wildlife Roadkill Reporting Systems in Europe**
It is not compulsory to report roadkill if it doesn't cause a traffic accident. Because of this the number of roadkill reported are far below the actual number, making monitoring a population of animals harder.

[20]**Effective Monitoring for Adaptive Wildlife Management: Lessons from the Galápagos Islands**
The Article acts as a guide for wildlife monitoring based on information they obtained from conducting wildlife monitoring on the Galapagos Islands. Herein they outline the importance of clear objectives, adaptability to changing conditions and circumstances, address common shortcomings in wildlife monitoring, and highlight the importance of making the findings widely accessible. They also offer guidance on methodology e.g., in terms of sample selection (representativeness), data collection, and management practices.

[21]**Modern Wildlife Monitoring Technologies: Conservationists versus Communities? A Case Study: The Terai-Arc Landscape, Nepal**
The article concerns itself with the impact of wildlife monitoring on the local human population, and how wildlife monitoring projects may alienate local human populations, when the results are not made accessible to these populations or when a large digital divide is present. Hence, it focuses on the societal and human impact of designing non-inclusive monitoring projects that consequently fail to consider the people in the area the research project aims to serve. These observations were made using a case-study of a wildlife monitoring project in Nepal and interviews the locals who were affected by it.

[22]**In My Experience: A Checklist for Evaluating Impacts to Wildlife Movement Corridors**
This article provides guidelines on the issue of wildlife monitoring to study the effectiveness of wildlife corridors, wherein it highlights that wildlife corridors may not always be sufficient or effectively designed but are often not investigated for effectiveness after construction.

Chapter 2: Identification of General Problems and Challenges

Identify 8-10 general problems & challenges from the list of publications in Chapter 1

1. Invasive American lobsters
    a. Ever since their introduction, red American lobsters have posed a moderate threat to freshwater ecosystems and have proven difficult to eliminate.
2. Alienated communities
    a. In rural areas, animal monitoring systems don't always consider the local human population. This results in local human populations feeling left out or ignored, which decreases support for animal monitoring systems.
3. Lead poisoning
    a. Study [15] has shown that birds appear to have high concentrations of lead in their blood, suggesting that human-caused lead pollution has already damaged the environment and accompanying wildlife.
4. Too tame wolfs
    a. Wolves in a park have gotten too accustomed to humans and they no longer run away. This have been "solved" by the authorities allowing people to shoot at the wolves with paintballs.
5. Feeding wild animals.
    a. Feeding wild animals can lead to them losing the ability to find their own food and an increased density of population which makes diseases spread faster it also makes them more aggressive towards people which causes them to be put down.
6. Harming of animals while monitoring
    a. Some monitoring methods can directly harm wildlife or disrupt their natural behavior.
7. Roadkill and misreporting of roadkill
    a. Roadkill is a threat to wildlife across the world, but you're commonly not obligated to report such incidents or even incentives to report it. Therefore commonly it gets over looked by many people.
8. Monitoring of insects and their influence on soil
    a. Insects can contribute greatly to an ecosystem's health and diversity, both above and below ground. While above ground, it's rather easy to track, below ground insects are more difficult. Also, soil biodiversity has an equally great impact on insects.
9. Lack of information regarding species leads to inaccurate results
    a. Is there an adequate knowledge of the species' biology and ecology in the location of interest? If the species are rare there may be too little information about their taxonomy, population status, or impact of threats and the results you get from the data you measured could be wrong.

Chapter 3: Identification of Relevant Problems

Identify 5 new problems you find relevant, urgent and interesting, not yet been addressed effectively

1. Roadkill (sensing number of cars driving past)
    a. Using for example speed sensors, you could detect when a car passes by and count how many cars drive past to get insight into traffic and roadkill possibility on roads.
2. Insect hotels (monitor types of insects)
    a. Due to climate change the number of insects decreases. This decrease of insects has influence on not only the insect populations, but on the whole ecosystem. By monitoring different types of insects by placing an insect hotel in the forest one can see biodiversity of the insect in this region.
3. Buxus moths
    a. Due to the introduction of the invasive Buxus moth in the Netherlands, many Buxus hedges have begun to die off. This could be monitored.
4. Wildlife corridors (sensing number of animals using Eco ducts)
    a. Across several places in the Netherlands, wildlife corridors are used to allow animals to cross busy roads. However, their effectiveness has not been properly proven. This could be better monitored.
5. Monitoring fish migration
    a. Several fish stairs across the Netherlands have dried up in recent years. Using sensors, it might be possible to get more insight into where fish move and where fish stairs are useful.
6. Monitor farmland birds
    a. Due to the decline of farms in the Netherlands farmland birds, the birds who live on those farms also reduce. By monitoring farmland birds one can see the influence declining farms have on the stability of those birds.

Chapter 4: Problem Selection and Motivation

Select from the list of the 5 problems identified in Step 1, one problem you would like to work on for your project. Motivate your choice

We have chosen for the monitoring of insects above ground, the surrounding soils and the impact of soil on the amount and diversity of insects. In particular, we want to solve the problem of unoptimized monitoring methods, as these can result in less accurate data and can be harmful to insects. Many current monitoring methods rely on human operations for the counting, which often makes the process much slower. We would like to automate this process to make it more effective.

We have chosen for this subject for a few main reasons:

1. Achievable
    - Insects can be found all throughout the Netherlands. As such, they are easiest to monitor and study effectively for the relatively small amount of resources we have.
2. Relevant
    - The population of insects in the Netherlands has fallen drastically in the last few decades. As insects influence soil and vice versa, this means this decrease might have extensive consequences on the environment and biodiversity.
3. Easy to implement extensively
    - Since insects can be found all throughout the Netherlands, any possible solutions can easily be applied in several locations, allowing monitoring to extend past any single location, resulting in more accurate data.
4. Can be expanded on
    - Due to its modularity, any possible solution can be expanded on, should the need arise after this project. Additionally, any sensors can be switched out for more accurate and cheaper sensors afterwards for better results.

Chapter 5: Potential Solutions

Find 5-8 potential solutions to your problem. Explain how these solutions could work

Monitored insect hotel

Using for example a camera or IR sensor, you could detect when an insect enters the hotel and count the number of insects occupying the hotel. Additionally, using AI, it might be possible to detect what type of insects use the hotel.

Monitored soil health

Soil health can be monitored by measuring the temperature, humidity and acidity of soil. This data could be collected and compiled into graphs to monitor and warn about soil health.

Pitfall trap

Pitfall traps are used to measure the number of above ground insects in an area by having a hole in the ground insects can fall into. However, these are often human operated, meaning the insects must be manually released afterwards. Both the releasing and the counting of the insects could be automated to increase monitoring accuracy and decrease the impact of the fall trap on the environment, as insects wouldn't get stuck in the trap permanently.

Sticky traps

Sticky traps commonly follow the same method as pitfall traps, except they're brightly coloured to attract insects and have a sticky surface, meaning insects get trapped in the glue, making it easier to count them. This counting process could be automated, in much the same way as previously stated with the pitfall traps.

Net traps (also called Malaise Trapping)

Net traps, also called Malaise Trapping, are large tent-like structures that guide insects to a large area where they can't get out. The insect flies into a vertical wall (made of nets). The response is flying upwards and guiding the insects to a large area where they can't get out. After you caught some insects, you can count them.

Monitor soil pestilence presence

One of the main threats to insects is the use of pestilence and chemical products in the agriculture community. It might be possible to monitor the contamination of the soil using a variety of sensors and study this data to analyse the effect of pesticides on an ecosystem.

Pan Trapping

Pan traps are trays filled with liquid set out to collect insects. Pan traps rely on color so, they attract insects because insects mistake them for food resources.

Nice article about different types of insect monitoring
https://www.frontiersin.org/articles/10.3389/fevo.2020.579193/full

Chapter 6: Solution Selection

Select 1 solution. Motivate your choice. Explain why you selected this solution over the other candidate solutions you found

Please present a modular approach to your project, i.e., your project should be composed of modules (ideally, each of you will work on 1-2 modules); the final product should be a merging/composition of the modules together.

Please add EXPLICITLY who does what in your project: Divide the tasks required among the members of your group.

We have chosen specifically for an automated pitfall trap. This was both a relevant problem and feasible to achieve given our limited time and budget. Additionally, it is extremely modular, meaning it’s easy to add extra elements and processes to it in case we might need them. For example, the base design is very simple, essentially just a hole in the ground. We can add however many elements we want to this to create more accurate and useful data.

Division:

- Product design – Candela and Eris
    - This entails the general product design, its appearance and uses.
- Electrical system – Fernando
    - This entails the physical components required for making the trap functional.
- Technical Design – Bas Liebe
    - This entails the technical design, including 3D models.
- Programming – Maaike and Claudiu
    - This entails the necessary code and software required for communication and control of the trap.
- Construction – Eris
    - This entails the final construction of the trap, meaning this task will be important all throughout the project.

Chapter 7: Methodology

Our solution uses passive sensing to detect when an insect enters the trap. In response, it activates a servo to lift the bottom of the trap to allow an insect to escape. Finally, it sends the acquired data to a central server. In total, it senses data, shares this data with external devices, and activates an actuator in response. This qualifies it as a smart environment.

In terms of construction, the main casing would most definitely be made with 3D printed PLA filament. If necessary, we might be able to construct some aspects with laser cut wood. For the microprocessor, we would use an Arduino Leonardo. For its power supply, most batteries would suffice, for example a 9V battery.
As for the sensors, we would need the following, for the basic (B) or advanced (A) circuit:

- Ultrasonic sensors (B)
- Arduino Bluetooth module (B)

For the actuators, we need:

- A servo motor (B)
- Camera (A)

The ultrasonic sensors would most probably require calibration, to eliminate background noise and red herrings. Most of this calibration could be done in the Arduino code using thresholds. If necessary, we might need to use capacitors to smooth out some of the electrical noise. (B)
For the camera, we would also need to calibrate camera settings to be able to take good looking pictures. A great deal of cameras, webcams for example, have this functionality built in or have libraries available. (A)

The product would be used in an outside environment, meaning it will need to resist the elements. As such, a special 3D printed casing seems suitable. The material that is most accessible to us is PLA filament. This should be strong enough to last a while, but it might not be the most optimal long-term solution considering it is partially biodegradable and might break down in the soil. However, it is the best material accessible to us at the moment.

Data would be collected passively without storing it throughout most of the operation time. If an insect is detected, an insect counter is incremented with an associated timestamp (B). For the advanced plan, this would also include a photo of the insect (A) and possibly an AI-operated statistic of the specific insect counted (A).

On a central device, the received data can be automatically visualized with a variety of graphs on custom-built applications. These can be time stamped and stored to study insect activity in different locations and at different times. Using this, a variety of graphs can be created, for example comparing hours, days, or months. (B) For the advanced camera technology, an AI could be used to recognize the type of insect.

This would require an entirely separate field of research and analytics, which would have to be studied in its own right. (A)
When an insect is detected, a servo needs to be activated to free the insect. This, in itself, is a form of automation based on the collected data.

The automated counting can be employed in nature and compared to traditional manual pitfall traps to check their effectiveness. As for the validating the detection, we can simulate insect activity by moving small material past the sensors in an animated motion. Since the sensors should be able to distinguish inanimate material from small organisms, the program should be able to distinguish moving and non-moving target. This can be checked by dropping small inanimate material to simulate non-moving objects, e.g., leaves and rocks, and moving small targets in front of the sensors to simulate actively moving objects, namely insects.

By automating the process, we make the process of counting and monitoring bugs more efficient. Since our process would include time data as well, the gathered information can also be more useful for study purposes. Additionally, due to the automated releasing of the insects, our automated solution should be less harmful to insects, since bugs don’t need to be stuck in the trap for a prolonged amount of time.

TIMEPLAN

Week	Basic plan	Advanced plan	Who does it
4	Chapter 7		-
5	- Sketches - Buy electronics(ultrasonic) Tinkercad - Understand Bluetooth module - Write introduction		-Candela -Fernando - Maaike, Claudiu and Bas - Eris
6	- 3d model - Circuit diagram - Control elements individually		- Bas - Fernando - Maaike and Claudiu
Vacation week			
7	- Assembling - Finish programming	- Add camera - Add camera slot - Program camera - Soldering (Candela)	- Fernando - Eris - Maaike and Claudiu - Bas
8	- Fix problems		-everyone
9	Final Demo		-everyone

Chapter 8: Validation

Validate your results through some tests and/or some scientific evaluation process

<To be prepared the 8th to 9th week>

Chapter 9: Results and Conclusion

Add to your document your results, findings and conclusions

<To be prepared the 8th to 9th week>

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