UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

The Beatles

Lars van der Valk
Sophie Brodkorb
Bente Lochtmans
Arthur Vafi
Koki Omura
Casper van Wijland

UNIVERSITEIT TWENTE.

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Chapter 0: Introduction

[0] Introduction to our report.

We are group 9; Our team consists of six people; Lars van der Valk, Sophie Brodkorb, Bente Lochtmans, Arthur Vafi, Koki Omura and Casper van Wijland. Each of our group members have an assigned role, the main roles are: Lars van der Valk who is our group leader and Casper van Wijland who is our secretary.

The problem that we chose to tackle and which was also connected to the subject, wildlife monitoring, is a problem that the small town of Heerde is facing. They have the problem that wild boars (Sus scrofa) enter the city and vandalise property/land.
We have created a product which can help Heerde solve this problem, our product is a device that can detect if there is movement nearby, if it senses that there is something in the vicinity, the other sensors activate which(if there is a wild boar in front of it) will activate the repellant system.

Our reasoning for choosing this problem, follows three principles, the relevancy, the timeliness and the importance. The reasoning for our problem follows the requirement of it being related to wildlife monitoring, as the problem is connected with wild boars. As for the timeliness of our project, we chose this problem because we found a lot of articles about it from the past year. Lastly as for the importance, currently the wild boars just get shot on sight, which is not nature friendly.

Our proposed solution is a product, our product is a device that can detect if there is movement nearby, if it senses that there is something in the vicinity, the other sensors activate which (if there is a wild boar in front of it) will activate the repellant system. The repellant system consists of a flashing light and an ultrasonic speaker.

We chose this as a solution because, when we did our research we found out this was the most nature friendly way to repel wild animals. We chose lights and a US speaker and not our other proposed ideas because they had a bigger impact on the ecosystem and they could impact the wrong kind of animals.

Chapter 1: Literature Review

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

[1] Precision wildlife monitoring using unmanned aerial vehicles:

Unmanned aerial vehicles (UAVs) serve as a new limit in environmental research. Their use has the potential to improve our ease of obtaining quality data. In the paper, they demonstrate that UAV-derived data has a much higher amount of difference in data compared to the conventional, on-ground approach. While UAVs increase our power of detecting population trends and precision, this does not particularly mean that they guarantee a greater estimate accuracy. Lastly, UAV-derived counts are consistently larger than the on-ground counted populations, this is because the perspective of the UAV(which is downwards) has a reduced likelihood of missed counts.

[2] Methods for wildlife monitoring in tropical forests; Comparing human observations, camera traps, and passive acoustic sensors

A large sum of the world's terrestrial wildlife is located in tropical forests. In tropical forests, it is exceptionally hard to monitor wildlife, due to the rough terrain and large quantity of vegetation which cause limited visibility. There are three main means of obtaining data on wildlife monitoring in tropical forests, these means are observations by humanism camera traps and passive acoustic sensors. In this paper, these three observation methods get compared via four separate rules, these decide which observation method is the best for tropical forest wildlife monitoring. This paper concludes that given the results they couldn't make a statement where one observation was better than the other, the results of the observation methods were always dependent on the context.

[3] Monitoring the mammalian fauna of urban areas using remote cameras and citizen science

The use of remote cameras has seen an increase in usage worldwide to investigate the behaviour of an array of animals. The amount of urban studies using remote cameras is surprisingly low given the fact that remote cameras may assist urban ecologists better than other means. Remote cameras may help urban ecologists better due to the fact that remote cameras can monitor a wide range of animal species while at the same time monitoring over a long period of time. Remote cameras might be a great opportunity for urban studies however, the chance of false triggers is still a problem. Despite the advancements of this decade in algorithms that are trained to automatically identify false triggers, human validation is still necessary for collecting data from remote cameras.

[4] Wildlife monitoring across multiple spatial scales using grid-based sampling

Genetic technologies help determine animal occurrence/abundance by using DNA to identify individuals. Population size or connectivity can be evaluated due to genetic monitoring and the historical status by retroperspective monitoring. One method to count individuals uses noninvasive genetic sampling. Multiscale gradient modelling helps to predict habitat quality and richness of organisms. The population level is also based on the landscape change and connectivity.

[5] Animal Recognition and Identification with Deep Convolutional Neural Networks for Automated Wildlife Monitoring

Automatic covert cameras/camera traps are an efficient and reliable method to monitor wild animals but they are really expensive, time consuming and also monotonous.
To identify those animals people/scientists need to analyse those pictures but because of the huge amount of images and quality of them it still takes a lot of time to identify. Therefore automated image recognition systems have been made like "Convolutional Neural Networks for Image Classification". Those are neural network-based learning models which take advantage of the 3 dimensions of a picture by layering them (Rectifier Linear Unit (ReLU) and pooling layer). Spatial structure, local connectivity and parameter sharing are essential to convert an input image into layers of abstraction.This system achieved more than 96% accuracy in recognising images with animals in them and was able to identify almost 90% of the 3 most common animals in that area.

[6] Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges

Drones or unmanned aircraft systems(UASs) are due to low operational costs, easier logistics, safety and reviewable footage easier to use for wildlife monitoring than aircrafts with onboard observers or satellites. There are e.g. fixed-wing UASs or hexacopters. The UASs are able to carry one or multiple sensors. They are usually equipped with a (thermal infrared) camera and the sensors are chosen based on the carrying possibilities, price and image quality. GPS devices are often used on UASs for geotagged images.
UASs were usually used for the detection of different species like large terrestrial mammals, aquatic animals or birds but UASs could also be used to estimate the population size.

[7] Going wild: what a global small-animal tracking system could do for experimental biologists

Tracking small animals (<300g) is not yet possible with technology in 2007. The technology needed for this is too heavy. In the This would give a lot of insight into migration paths, maximum flight distance and other metrics. The paper is quite outdated when looking at technological advancements since then, but the general goal of the paper can still be applied. An example on improved tracking devices as shown in source [8]. These make use of powerful receivers and less powerful and therefore smaller senders (tracking devices on animals).

[9] Bee hive traffic monitoring by tracking bee flight paths

The flight path of bees indicates a lot about colony strength, health and colony structure. The paper mostly focuses on the system for tracking them. The biggest problem is recognizing bees, shadows and 'noise'. Noise is anything which is not a bee. The system works fine and gets data. The processing of this data into workable information for beekeepers is the next step. Also upgrading the camera and angle of lens would increase the quality of the data and number of bees tracked.

[10] WILDSENSING: Design and deployment of a sustainable sensor network for wildlife monitoring

Creating a wildlife sensing system needs a lot of thought. Rapid field-ready prototyping was the way to do things for the researchers working on this project. The design consists of three parts: an RFID tag around the neck of badgers, receivers at well known 'badger spots' and sensor nodes set up around the forest to track micro-climatic conditions. The main phases were software design and redesigning power-hungry nodes. Maintenance is one of the aspects which got little attention and would become a problem during field testing.

[11] Long-term monitoring of wildlife populations for protected area management in Southeast Asia:

In order to improve long-term biodiversity monitoring in protected areas (PAs), empirical data was gathered over the course of 10 years in the Keo Seima Wildlife Sanctuary in Cambodia. Abundance estimates of 11 species between 2010 and 2020 and spatial distributions for 7 species are given. Arborial primates and green peafowl had stable or increasing populations, while ungulates and semiarborial primates were in decline. This may mean that ground-based threats to these species, like snares and domestic animals are having negative effects on these species.

[12] Application of DNA barcodes in wildlife conservation in Tropical East Asia:

Tropical SEA is losing biodiversity faster than anywhere else. DNA barcodes, 'short, standardised DNA sequences' can be a useful tool to improve data availability as they are a minimal-impact solution.

[13] How does human-induced environmental change influence host-parasite interactions?

Parasites and their interactions with their hosts are an important field of study, required to understand the workings of an ecosystem. The effect of human interference on a wildlife habitat can be detected in the study of parasites. The two crucial factors determining parasite behaviour are encounter rate and host-parasite compatibility.

[14] Terrestrial animal tracking as an eye on life and planet

The improvement on tracking animals over the years mostly shows in smaller devices, live GPS updates and improving energy sources such as batteries versus solar powered devices.
The ethical point of tracking animals is an important part of wildlife monitoring. The way that this is talked about in the article is the great impact monitoring has on the lives of the animals, because they could be more at risk for predators and the data will be off because the animals will behave differently.

[15] Tracking animals in freshwater with electronic tags: past, present and future

This article talks about locating and tracking animals in water. For example fish, turtles, frogs or otters. Because it's hard to use visual observation techniques they mostly used electronic devices that send out signals from a transmitter to a receiver, like radio telemetry, or tags that they call "passive integrated transponders". Apart from electrical data, it's also more and more common for freshwater systems to use physical data like temperature, and pressure from sensors (biologging) to get a complete view of the habitat and behaviour of the animals.

[16]A Radio-Tracking System for Wild Animals

This article talks about making small harnesses for small rodents to track movements. It uses radio sensors that work with indicators. The power source is a 20 gram battery, the power goes through an oscillator to the transmitting antenna to the receiving antenna. Then it goes to the receiver and into the indicator.

[17] Monitoring diversity and abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan

In this research, a method for capturing a group of target species with a given probability in a given area with the most efficiency is addressed. This is mainly because Investigating the wildlife abundance by camera-trapping needs some certain requirements such as how many photographs should be made, what kind of trap does it need, how long should the camera be used etc. This thesis is about what is the minimum load of work that is required and its guideline for trapping using a camera in wildlife monitoring.

[18] Monitoring free-living Japanese Bush Warblers (Cettia diphone) in a most highly radio contaminated area of Fukushima Prefecture, Japan

During the great east japan earthquake in 2011, the Fukushima nuclear plant unit 1 has exploded causing radioactive contamination abound the surrounding area in Fukushima.
In this thesis, Japanese Bush Warblers in Fukushima were investigated through wildlife monitoring and it resulted in capturing some extraordinary changes on their bodies.

Chapter 2: Identification of General Problems and Challenges

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

Challenges that apply to us:

- Expenses for the cameras/sensors
- The terrain needs to be accessible.
- The remote cameras may record false triggers, such as pets
- Algorithmic advancements are not good enough and still human validation is still required for collecting data from the remote cameras.(due to the false triggers)
- Animals are hard to see/identify in certain areas (due to light, shadows, ground cover)
- Technical limitations
- Unusable data which is reliable but cannot be applied
- Maintenance of sensor networks for wildlife monitoring
- The project needs to be ethical.

Challenges that we also found but aren't applicable:

- UAVs aren't cheap
- UAVs might get mistaken for enemy aircraft
- Some laws make it difficult to implement drones/UASs
- Tracking systems are too heavy and intrusive for animals <300g
- Nuclear power has a lot of advantages and benefits in its energy efficiency and eco-friendliness(while it is working without accidents), however it may still have some trouble in terms of safety for humans, the environments, wildlife and biodiversity around the area.
- The battery weight and the length of the antenna are inconvenient for small animals.
- The challenges have mostly to do with attaching the sensors and devices to the animals and the technical performance of the devices.
- Very little is known about the mechanisms that determine parasite behaviour.
- The amount of data on wildlife trends in certain areas is very poor and much more research is needed in these areas to accurately measure populations.

Chapter 3: Identification of Relevant Problems

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

The first problem which interests us is the problem of wild boars getting into cities and villages. In the Netherlands it is especially a problem for the village Heerde. According to Omroep GLD the residents have invested in anti-boar fences and some are afraid while taking their dog for a walk [19]

The second specific problem which is interesting to us is the wolf which is back in the Netherlands. The past month there were some encounters on the Veluwe with a wolf which got accustomed to humans[20]. This can create dangerous situations, such as wolves coming very close to people. It also divides the country in a big debate on how to handle this issue. [21]

The third interesting problem is the amount of foxes in big cities in the UK. London is a prime example, according to The London Wildlife Trust there are an estimated 10,000 foxes in the city[22]. If these foxes could be monitored it would give a lot of insight in the urbanisation of their 'wild' lives in cities.

In Nara, Japan, there are over 300,000 people and 1,000 deer living together sharing the place without barricades in between. The deer are so in trust with humans that they even cross the street as humans do and are harmless whenever people approach them[23].
There might be a need for some ideas to make the city better for both human and deer safety.

The fifth problem is that there are animals that are invaded by humans due to rapid modernization and city expansion. In South Africa, there is a town that is 25 miles away from Cape Town where African penguins are living with humans and only two percent of them remain in comparison with the population back in the 20th century[24].
Some species are in danger of extinction because of human invasion of wildlife habitats.

Chapter 4: Problem Selection and Motivation

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

For the final problem to work on, we need something that is realistic to address. The wild boars roaming into cities is the most promising problem. We would like to focus on the town of Heerde. There are quite a few news articles on how people cope with the boars in their town. [19][25][26] Hopefully we can get in contact with locals and professionals in the area to gain a deeper understanding of their problem. The goal for us is to look at the possibilities of sensing boars and come up with a smart, harmless solution for the town, its people and its boars.
Creating some autonomy in this system should be feasible and therefore we think this problem fits within the scope of the project.

The other problems did not make the cut to be selected for our project.
The wolf problem is such a widely known problem about quite a small population of animals. The question is if this is really a problem which requires a smart solution.
The foxes living in London is not a new problem and does not necessarily cause problems. The people living in London have changed their behaviour and some are so friendly and confident towards humans that they are almost domesticated[27].
The problem with deer and humans in Nara, Japan is somewhat similar to the problem in Heerde. Again it is the interaction between humans and wild animals in an urban environment which can cause dangerous situations.
Then lastly we have the problem of humans building in already existing wildlife habitats, it is a wildlife problem, but caused by humans. This is an interesting problem in itself but is less suitable towards this project when looking at the implementation of wildlife monitoring and automating a solution towards the problem.

In conclusion, the wild boar problem in Heerde is most applicable to the project definition due to the possibility of getting in contact with locals and professionals, the amount of information retrievable from the internet and the clear problem which presents itself in the town.

Chapter 5: Potential Solutions

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

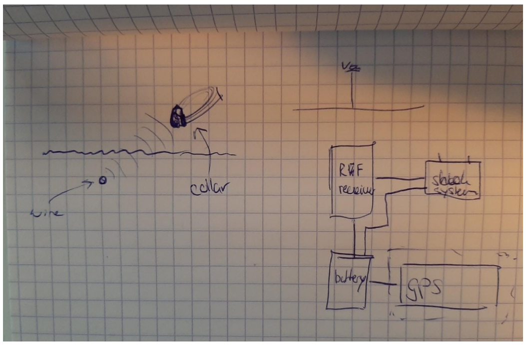
Shock collar

This solution is based on the shock collars which are used by dog owners to keep their dogs on their property. These work with an underground wire which sends radio signals to the collar which then can release a shock or high tone.

If every boar would be collared with a working collar this could specifically repel boars from Heerde in theory. In practice, it would need to be checked if these boars react to a shock, do not then decide to run away into Heerde and see if the collars are durable enough. Since boars are quite large animals, the shock collar needs to fit well and would allow us more space to work with inside the device than with a dog collar.
The hardware requirements for this solution would be the underground wire which needs to be put around the side of Heerde where boars enter the town and the collars. These can then work together as a smart system. The software is quite simple, if there is a radio signal detected, then it sends a shock. If there is nothing detected, do not send a shock.
There is a possibility to make it smarter and allow it to retrieve more data which could help with monitoring the animals.
Another risk would be that the boars do not dare to cross back over the line if they crossed it into the city once. This could be fixed by being able to turn certain sections off to allow the boar to get back into the forest.

Validating is going to be quite hard working with real boars and shock collars, it would be more feasible to evaluate it using a buzzer or light to see a proof of concept. The presentation could be done in the same way. Testing and validating the design on boars would also be quite a difficult task. Testing it with different outputs, as mentioned lights or sound would be possible.

Most collars need to be recharged every 3 months.



Smell

Smell repellent, through odour sticks and sprays, the smell is called "huile de cade vraie".
We have two variations on the smell repellent, either sensing and mapping where most boars cross the road and go into people's garden, and putting smelling sticks there in the ground; or having sensors that sense the boars and react with smelling spray, to scare the boars away.

The smell repellent would be a 'complete' solution to the boar problem since the boars wouldn't go into the city anymore if it works well enough.

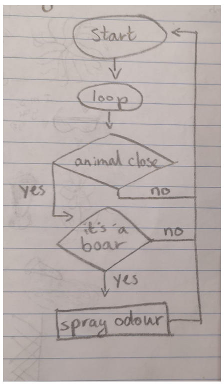
The risk that comes with using smell is that it may repel other animals as well, like neighbourhood cats, and it might smell bad for humans too, that way it inconveniences us too much for the solution to work.

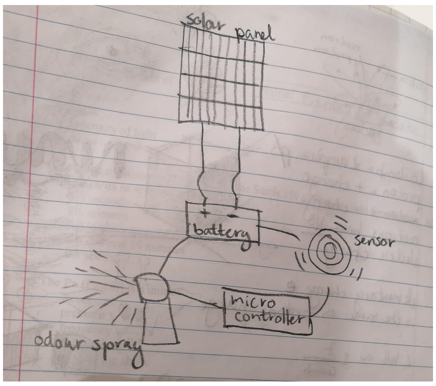
For the sticks we need: the sticks, the sensing system, the charging system, and humans to replace the sticks if the smell has faded.
For the spray we need: an automatic spraying system, the sensing system, the recognition system, the charging system. (and humans to refill after it's empty)

The impact is that the smell is bad, so humans smell it as well. And other animals might be impacted that we don't want to scare away.

To figure out if it works we have to find out how bad the smell really is and if it affects boar behaviour in the long run, because that's what we want to achieve.

We are going to present it with a scale model.

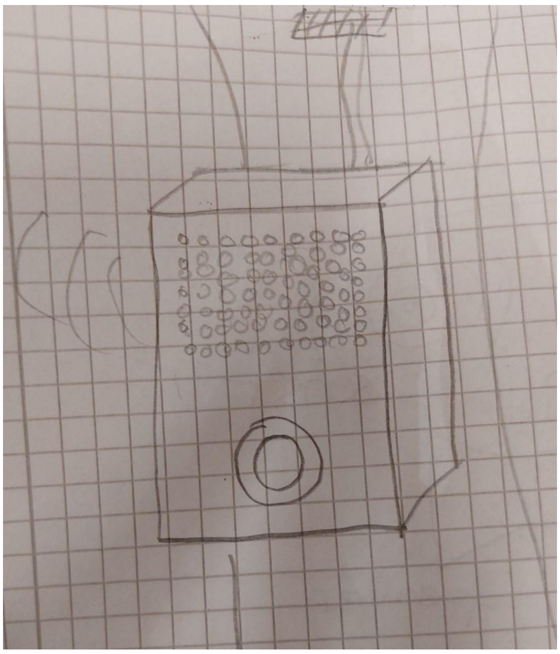


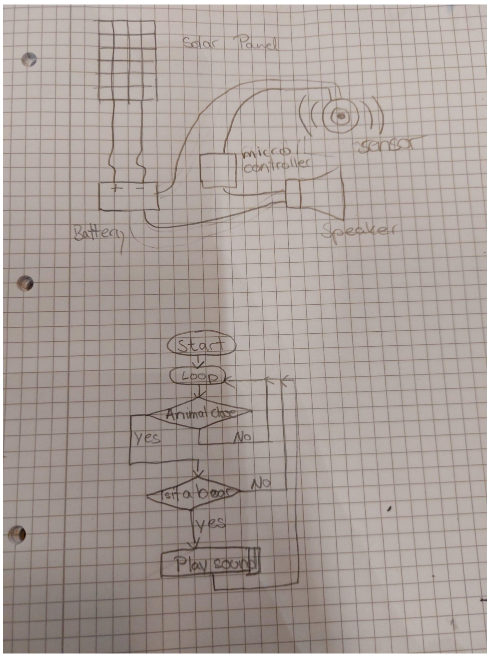


Ultrasonic

One solution would be to use ultrasonic repellents which use soundwaves to repel wild boars. This can be accomplished by sensing the wild boars with any sensor (for example cameras or microphones). If those can identify the wild boars the repellant would start using the soundwaves so the boars would go back into the forest and not closer to the town.

That could solve the problem of wild boars entering the town completely. Since humans can not perceive this sound and animals just perceive it as unpleasant the only risk would be that other animals could hear it as well. The requirements would be the monitoring hardware, depending on which one we would also need a wild boar detection software, as well as the ultrasonic sound generator/speaker. Humans would not be involved.
This solution has the potential to repel boars without harming them, other animals or the environment. But even though it's not harming any of those it could still scare other animals.
To figure out if it works we would check if data of repelled boars already exists. And we would probably show it off by using a small scale model.





Compressed air

This solution is based on the principle of compressed air, since compressed air doesn’t particularly need humans to refill this made compressed air as a repellent, an interesting option. Compressed air however does not solve the problem completely. Because the boars that (might) get scared, could run in the wrong direction.

This concept comes with a risk however, since we want to make the process automatic with a solar panel, new air gets compressed into the can. The risk here though is that the system might compress too much air, which results in the can exploding. The hardware that is needed for this repellant to be automated are; sensors that check if there is a wild boar nearby, a solar panel and an air pump that can compress air into the can. The software that is necessary is the following algorithm: an algorithm that turns the air pump on to compress air, this algorithm also has to check if it isn’t pumping too much air into the can.

This should be a ‘complete’ solution as it addresses all parts of the problem.

A risk might be that the can that holds the compressed air might get too compressed and explode.

The required hardware is: a sensor that senses if there is a boar in the vicinity, something that encapsulates everything. A can that holds the compressed air. A solar panel so that the can is able to get the power it needs to refill the compressed air can.

And the required software: an algorithm that turns on the air compressor so that new air gets compressed into the can. The algorithm also has to have a limit in how much air is compressed. An algorithm that detects if there is a wild boar nearby.

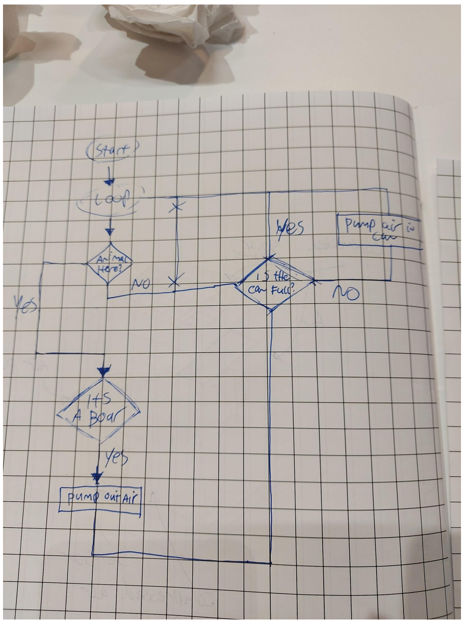
Humans are not particularly involved, they’re mostly necessary for maintenance.

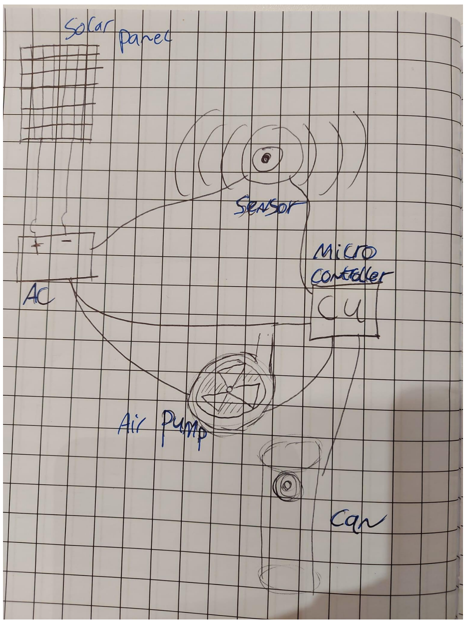
Potential: it could be possible that it will be able to repel boars.
Impact: There is no real impact on the environment, the only impact it might have is if the tech isn’t smart enough that it will react to animals similar to boars.
Or the explosion of the compressed air might have an impact on the area.

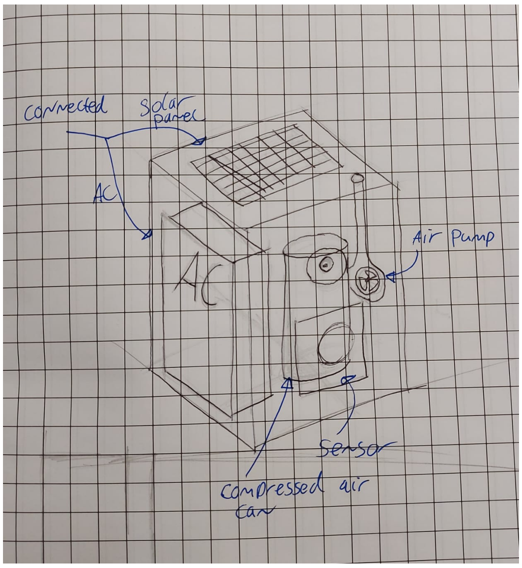
You could place cameras on a few locations to validate the system.

The system can be demonstrated with a functioning small scale replica.

Although compressed air would be a nice repellant as an option, the range of compressed air isn’t that high. This is why compressed air is probably not a great solution. However, the sound of the air might scare away the boars.
Model:


Start
Loop
Animal here?
NO
Yes
Is the can full?
Yes
NO
Pump air in can
Is A Boar
Yes
pump out Air


Solar panel
Sensor
Micro controller
CU
AC
Air Pump
Can


connected
Solar panel
AC
AC
Air Pump
Sensor
Compressed air can

Light and water

In order to keep boars from entering and ruining certain areas, a system could be set up that detects them and scares them off. A possible solution for this could be a precise water gun paired with a powerful flashing light. The setup would need to use a reliable method to detect a boar in its proximity. A heat camera, paired with recognition software could be used for this. Also, the boars could be tagged with an RFID identification collar, making it possible for the system to recognise them. If they approach for the first time, water can be sprayed together with light. After the first time, only light may be sufficient because of the association effect.

This should be a complete solution as it focuses on the boars not entering the places they shouldn't. The goal is to eventually train the boars to stay clear of the urban area altogether.

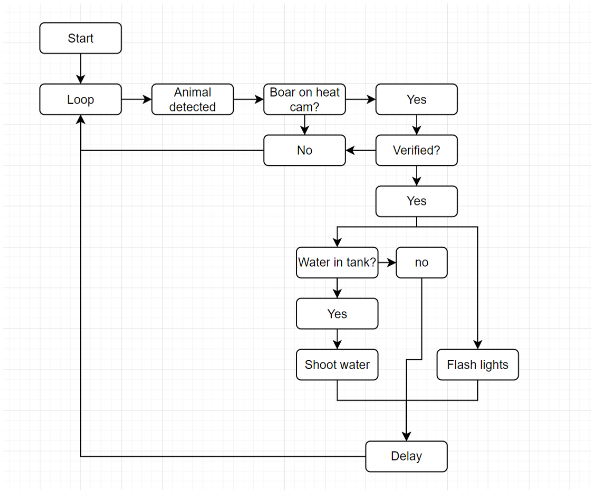
There is always the possibility for the repellents to affect other animals. The boars also might become accustomed to the system and ignore it after a while. Testing and research will need to point this out. Also, the boars need to be able to survive outside of the

The solution requires hardware to be set up at a number of strategic locations. The hardware needs power and a water source. It needs to be able to accurately shoot water and flash light at the boar so that it is scared off. It also needs sensors to detect if a boar is approaching
On the software side, a smart sensor system needs to be set up that can identify boars from other animals and detect if they are coming too close to the protected area. It also needs to communicate with a central system so the boar encounters can be mapped.
The system might need maintenance every so often.

The system has the potential to chase off boars when needed. If done correctly, it could mean that current methods can be replaced with a smarter one.

First we need to verify whether or not boars will be repelled by the light and water. After that we need to test if the software can accurately detect a boar and distinguish them from other animals.

A scale model with a visual representation of the software and hardware at work could demonstrate the system quite well.



Feeding

This solution focuses on removing the need for the boars to enter the town, instead of scaring them off. The idea is to feed the boars elsewhere so that they will not need to go into the town in search of food.

This would solve the problem partially, because the wild boars might learn the method and how it works and can be ineffective at a certain point.

A risk could be that the wild boars might be unsatisfied with normal food in the forest and fully dependent on the food provided by the dispenser.

In terms of hardware we need a sensor that can detect that wild boars are near the dispenser and dispense the food in front of them. There will be a need for replacement of food in the dispenser as well as minor maintenance on it. For the power supply, we will have to use solar panels to be able to work it out.
We need software that can detect whether the detected object/animal is a wild boar or not.
Also, it should be able to give a notification that the food in the dispenser is either expired or run out.
Humans are needed for replacement for the food and minor maintenance.

This system could prevent wild boars from entering the city/human settlements.
The negative impact would be that it might accidentally feed other animals as well and it can affect the entire ecology around the area.

We could test the high-fi prototype in the actual forest, but a demo setup would consist of a scale model with arduino and sensors.

Chapter 6: Solution Selection

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

Most of the solutions mentioned above have some major flaws. Some are not fully self-operating (like the smell canisters needing to be refilled) and others require too much infrastructure (like the water repellent). What is needed is a feasible idea that has a high chance of being effective and can be validated. Therefore, the working idea for this stage of the project will be to use a combination of light and ultrasound to repel the boars. The detection will be done with a heat camera and verified at a central hub to avoid false positives. The verification method is still up for debate, but currently this seems like a workable solution. The detection points will communicate with a central server to gather information on the behaviour of the animals, making it possible to evaluate the effects of the system. The system will consist of two main parts: the detection system and the repellent. These two modules will need to be developed and tested separately and then integrated together.

This option is:
Feasible, because it relies on relatively cheap and simple technology.
Effective, or at least promising, because it could work very well in humanely scaring off the boars without causing trouble for people or other animals.
Easy to validate, because it can be broken up into individual steps that can be tested.

Below is the schedule that we made to divide the tasks for the coming weeks.

Getting in contact with Heerde	1	Bente	Next week
Ordering hardware if needed	1	Arthur	Next week
Prototyping Hardware	3	Casper, Koki, Arthur	After break
Prototyping Software	3	Casper, Koki, Lars	After break
Research implementation options	1	Sophie	After break
Set up validation (testing)	2	Bente, Sophie	After break
Set up final presentation	1	Lars	After break

Chapter 7: Methodology

Think of your methodology to follow: Which equipment you need, data collection, data use/analysis*

** Methodology would be re-defined based on your experience. Do not worry if it is not concrete. It is not binding to what you will do eventually, but more like a guide for you.*

Our Methodology:
Deciding on what methodology we are going to follow, we have considered the following points. First of all: what is a smart environment? A smart environment is a world where different devices can sense and act on themselves. Why does our solution qualify as a smart environment? Our solution qualifies because our project, if there is movement in front of the camera, can sense if it is a wild boar. When it senses the boar it will act accordingly, in this case, it will activate the repellant system that we are going to create. While it senses if there is a boar in the vicinity, this data will be sent to a central hub, central hub uses this data to identify weak spots. Furthermore, the central hub can send this data to the locals to warn them about wild boars.

Equipment
Next up is the equipment that we need for the project. For our solution, we of course need a sensor to sense if there is movement and a sensor that senses if the movement corresponds to a boar. Furthermore, we need the repelling system, in this case, to make use of a light that can produce a lot of light and an ultrasound speaker that can reach a certain frequency. In chapter[8] we mention that wild boars hear up to 40.5 kHz which is much higher than what humans can hear(20 kHz). In paper **[28]** & **[29]** we read that boars get scared of loud sudden noises.

Next up are the case to encapsulate the hardware in, power-related equipment such as a solar panel and a rechargeable battery to make the product able to sustain itself. Lastly, we need the product to be able to send the data to the central hub, this is possible via something like a sim card. The product also needs to be placed either on a tree, pole, box or cables.

List of necessary purchased (hardware)equipment:
- A heat/infrared camera.
- A distance sensor(Ultrasonic/Infrared).
- Lights that can flicker and scare off the boars(LED strip).
- US speakers.
- Power (solar panel, rechargeable battery).
- Connectivity and central server (sim card/bluetooth module).

Calibration
The sensors themselves won't need calibration. The calibration of the system is done in the software. The software of course needs to use the sensed data and check whether there is indeed a boar and if it should act accordingly. If the software is not calibrated the contraption may still act, when sensing something that is not a boar, or it may not act even though a boar is present.

Next up is the question of whether the equipment needs to be used in a controlled environment or not. Our product will not be used in a controlled environment, it is going to be deployed in a forest or on the border of a city (in this case Heerde). Because we are not going to use it in a controlled environment we are going to need a special casing for it, so the boars will not destroy it or so the hardware won't deteriorate. So in short, we will **not** deploy it in a controlled environment, in this case the non-controlled environment will be the forest-(sub)urban border of the town. If we want to deploy it there we would have to get in contact with for example the foresters of Heerde. Calibrating a product won't take long, for example the calibration can take up to one week, where a human checks for positives and false-positives.

Data
Data will be collected via the cameras that are on the product. The camera will collect this data if it senses movement in front of it (animal encounter/weather/surroundings). This data will be analysed at the central hub. The central hub can analyse whether the encounter data indicates boar hotspots. The central hub can also analyse which sensors encounter more boars than others. With this data the central hub can conclude the product's effectiveness. Effectiveness should also include if the boar slips by and enters the city. Combining all this data with animal encounters, weather and surrounding data the central hub can predict boar behaviour. The automation of the product goes as follows: if the product senses movement, it will check if it is a boar. If the encounter is indeed a boar, the bright lights and the ultrasonic speaker will activate to scare the boar off.

Validation
The validation for if there is indeed a boar in front of the camera should first be verified by a human for x amount of encounters so that the program can more easily detect if there is in fact a boar in the proximity of the product. The effectiveness of our product can also be checked in terms of damages, as recorded damages pre-deployment and recorded damages post-deployment.

Validation for if indeed the light and ultrasonic speaker work should be able to be validated via online research(papers) and via recorded boar encounters, will the boars just relocate close to the city or will the boars indeed flee? Validation of sensors should be able to be done in a controlled environment(small scale). The combination of all software and hardware should be able to be validated by using it in the field.

How our methodology works towards the solution of the selected problem
How does my methodology lead to a solution that solves the problem under study?

By splitting up the solution into parts we are able to give everybody manageable tasks. These tasks are: getting in contact with Heerde, ordering hardware, prototyping hardware, prototyping software, researching implementation options, setting up validation testing and setting up the final presentation. By working on these tasks in separate groups multiple parts of our solutions can be worked on at the same time.
This should lead to a solution which helps alleviate the boar problem in Heerde. The end goal would be a defensive line on the edge of Heerde. The goal in our project would be a part of this system worked out. One of the sensing/deterrence poles working and running which can distinguish the difference between different moving objects. The whole system could be illustrated by a mock-up small-scale model of the surroundings and the positioning of our solution.

Basic and ambitious plan

The basic plan for us is to make a detection and repellant system. Therefore we need an activation of the detection system by a lower-energy consuming sensor like an infrared or motion sensor. After those would be activated a heat camera will turn on to detect an animal body and if that is the case a repellent system, in this case sound and light, will be activated. It is also essential to make our casing weather proof and provide a power source.

As an ambitious plan we want the system to be able to differentiate between boars and other animals which could be done with artificial intelligence. Another point would be to scare the boars more precisely as well as mapping the data. With that we can check the amount of boars and identify hotspots and study their behaviour and reaction to our system. This data could also be used to warn drivers or inhabitants if a boar is close by with the help of an (already existing) app like Google Maps or FlitsMeister. And at last a self-sustaining power supply would be important as well by using solar panels and a battery.

Once we are done with the basic plan we will use parts of the ambitious one bit by bit.

Planning

6	**19-dec.**	R&D Working on solution			Worked out hardware needed + Ordering of hardware needed + first drafts for software and hardware	**DL: Chapter 0 Introduction**			
x	**26-dec.**	-	-	-	-	-	-	-	-
x	**2-jan.**	-							
7	**9-jan.**	R&D Redefine methodology/ how to test							Testing methodology and product done
8	**16-jan.**	Testing				DL: Chapter 7 (if changes) + Product testing			Presentation done
9	**23-jan.**	Finalization					**DL: Chapter 8 & 9 Test results, findings, conclusions + Final Demo**		

Chapter 8: Validation

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

Validation of using light and sound
Sound is an effective repellent against wild boars. In a different research they stated that sound repellent reduced the crop damage which was caused by wild boars was reduced by 67% [28]. Even Though the paper stated that light repellents are not effective and boars get used to it, we decided on keeping that idea since we are using the flashing lights in combination with the sound repellent and only when the boar approaches so they will not get used to them.

We are using a sound of more than 20 kHz since humans have a hearing range of about 20 to 20 kHz. A research paper states that pigs in comparison can hear in the range of 42 Hz to 40.5 kHz [29]. Since wild boars are the same species it should be similar.

Testing the working of the heat sensor in combination with the distance sensor on the prototype
We need to test if the heat sensor works by putting cold objects in front of it. Because when you put something in front of the sensor the distance sensor activates the infrared sensor, so to see if it works we put something cold in front of it that doesn't reach the desired temperature, if it's a cold object in front of the sensors the lights and sounds shouldn't turn on.

Testing the working of the distance sensor on the showcase
To test the sensor in the showcase, if your hand has the desired temperature and you place it in front of the sensor, the led lights will start to blink and the buzzer will start to make a noise. By the results of this showcase we can conclude that the device works.

Testing the communication between the sensors and the laptop
The prototype should communicate to the showcase, and the showcase should communicate to the laptop. If you place your hand in front of the prototype, the laptop should show that there's something in front of the sensor. If you place something in front of the showcase sensor, the laptop should show that there is something in front of the sensor. If you place something in front of both, the laptop shows both. This means the communication works.

Results of validation
The testing to see if there's a boar detected by the sensor, has been tested through using the testing methods described in the paragraph before, on a smaller scale than we originally planned. Instead of a boar, we used a human hand. It worked. The sensors of the prototype worked, because when you put a hand in front of it the lights blink and the sound goes off, but when you put a cold bottle in front of it, it doesn't go off. And if it detects a warm presence, the computer shows that it picked up on a "boar". The testing of the showcase is also done with something other than an actual boar, since a boar is too big. We used a piece of paper with a boar drawing on it and the light went blinking when it detected the "boar", so it worked. This also came through, through the computer.

Chapter 9: Results and Conclusion

What was our goal

A basic and ambitious plan was set up at the beginning of our methodology. The basic plan was almost reached. A heat camera was turned on to detect a warm body by a low powered sensor. This could detect the difference between a cold object and a warm object.
The waterproof casing was not achieved since we lack the resources to create a weather sealed casing. In the current prototype the casing is made of laser cut 6mm triplex plates.
The system can not differentiate between boars and other warm blooded animals. This goal turned out to be quite difficult since an 8x8 pixel infrared camera was around 50 euros. 8x8 was too low of a resolution to differentiate a hand from an indoor environment at 20 cm away. Only specifically targeting boars with the deterrence was not achieved. It now deters in any unspecified direction.
The data mapping was achieved. The sensors can communicate with each other and relay this information to a central hub. In our case this was one of the two ESP32's attached to a laptop.
With this information we could identify hotspots and then double check their behaviour at these hotspots to see if our system has the intended reaction.
Further spreading this information into drivers apps would definitely be a possibility. In this project we did not have the capability and time to integrate this. We also did not achieve making contact with the municipality of Heerde or an (existing) drivers app.
The implementation of a solar panel was not achieved. The system does work on its own with a power supply. A solar panel could be added on to recharge the battery.

What were our limits

We were quite limited by a few factors in this project. The first factor was the budget of 70 euros which was a lot, but not enough for a high resolution infrared camera sensor which resulted in a lack of interpretable images. This results in a picture with too little information to train artificial intelligence with. This knowledge prevented us from trying to create an Artificial Intelligence system.
The second limiting factor was our lack of response from the municipality of Heerde. We emailed them several times asking for more specific information on their problem. None of our emails were answered.

What would we do different next time

During the process of building our system we lost track of a few main points we discussed in the beginning of our project. This applies to the solar panel and the weather resistant encapsulation of our system. Therefore it would be good to check in on the main goal each week of the project. Lastly, the meetings we had in the first seven weeks of the project were only on Thursday afternoons. In this we were able to finish everything needed for the deadlines. An extra meeting at the beginning of the week to get everybody up to speed could be an improvement.

Conclusion

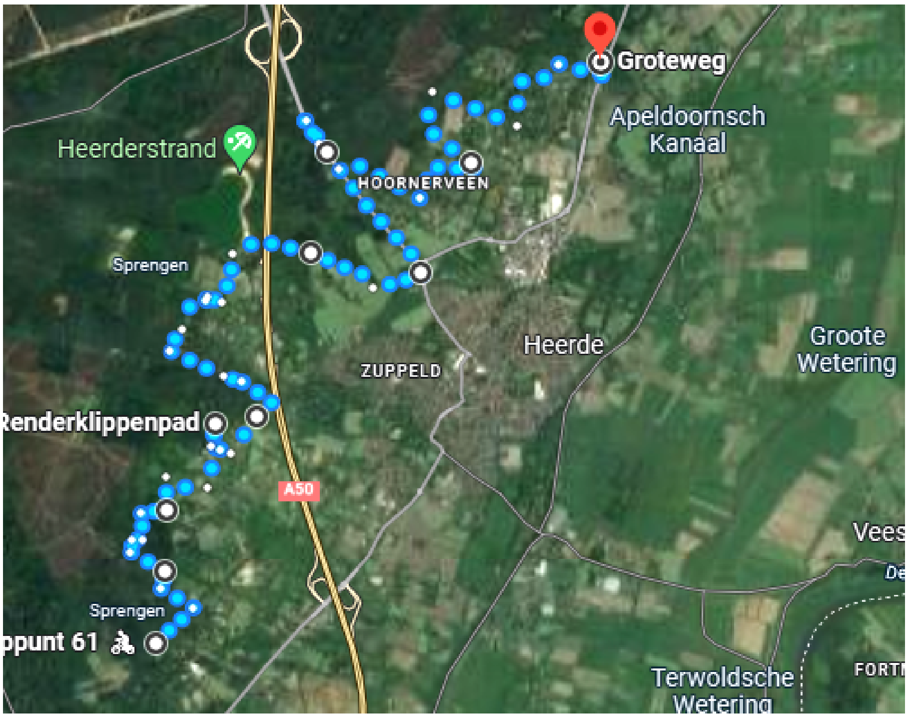
Creating an accurate boar detection system is quite complex. Therefore, the prototype created is only a proof of concept. This system, when implemented with the right sensors and budget, could probably work. The limiting factors of time, money, experience and networking proved to be quite substantial. The finished prototype cannot distinguish boars specifically but works as intended for this project. It can distinguish warm from cold objects under the sensor box. The network is also a proof of concept since it only uses two nodes. These two nodes are able to communicate and relay information to the central hub. For the final result, see *picture 1* on the right.

[picture 1]

Chapter 10: Discussion

To implement our repellent system in the real world we needed to find suitable spots to place our system. For those we need to take into consideration a few important factors. One of them would be that our system should not face the streets since it flashes lights and drivers or bikers can be scared. Not only do we need to take vehicles into account, walking ways should not be affected by the flashing lights either. The sound should not be a problem in this case since it is out of our hearing range as stated in Chapter 8.
The same goes for the distance to houses or residential areas. It would be problematic if the local residents get annoyed by it, so we need to make sure that it has a big enough distance to them. Another thing that we would need to pay attention to is the law, since we are sending data about if we detected boars and where they are. Our system should not affect humans since we are not using cameras or violating privacy rights.

The spots that are the most important to put our repellent system are either close to busy streets to prevent car accidents, close to residential areas that are close to the woods and places like football fields or for example a golf course which is right next to the Heerderstrand. Those spots are important so the boars will not devastate the garden/ground.
We would attach them to trees or poles 2 metres high. The track we would put our repellent system on is shown in *picture 2*. The distance in between each system should be around 200 metres to make sure all the data can be sent even if obstacles are blocking the direct path. The 'ESP32' can send data up to a distance of 480 metres using 'ESP-Now' [30]. Due to the length of the track, which is around 13 kilometres, we would need to put up 60 to 70 of our systems to let them communicate with each other and keep boars out of Heerde.



[picture 2]

Bibliography

[1] Hodgson, J. C., Baylis, S. M., Mott, R., Herrod, A. & Clarke, R. H. Precision wildlife monitoring using unmanned aerial vehicles. Sci. Reports 2016 61 6, 1–7 (2016).

[2] Zwerts, J. A. et al. Methods for wildlife monitoring in tropical forests: Comparing human observations, camera traps, and passive acoustic sensors. Conserv. Sci. Pract. 3, e568 (2021).

[3] Anton, V., Hartley, S., Geldenhuis, A. & Wittmer, H. U. Monitoring the mammalian fauna of urban areas using remote cameras and citizen science. J. Urban Ecol. 4, (2018).

[4] McKelvey, K., Cushman, S., Schwartz, M. & Ruggiero, L. Wildlife monitoring across multiple spatial scales using grid-based sampling. undefined (2009).

[5] Nguyen, H. et al. Animal recognition and identification with deep convolutional neural networks for automated wildlife monitoring. Proc. - 2017 Int. Conf. Data Sci. Adv. Anal. DSAA 2017 2018-January, 40–49 (2017).

[6] Linchant, J., Lisein, J., Semeki, J., Lejeune, P. & Vermeulen, C. Are unmanned aircraft systems (UASs) the future of wildlife monitoring? A review of accomplishments and challenges. Mamm. Rev. 45, 239–252 (2015).

[7] Wikelski, M. et al. Going wild: what a global small-animal tracking system could do for experimental biologists. J. Exp. Biol. 210, 181–186 (2007).

[8] Gottwald, J. et al. Introduction of an automatic and open-source radio-tracking system for small animals. Methods Ecol. Evol. 10, 2163–2172 (2019).

[9] Magnier, B., Ekszterowicz, G., Laurent, J., Rival, M. & Pfister, F. Bee hive traffic monitoring by tracking bee flight paths. 10 doi:10.5220/0006628205630571ï

[10] Dyo, V. et al. WILDSENSING: Design and deployment of a sustainable sensor network for wildlife monitoring. ACM Trans. Sens. Networks 8, (2012).

[11] Nuttall, M. N. et al.
Long-term monitoring of wildlife populations for protected area management in Southeast Asia. Conserv. Sci. Pract. 4, e614 (2022).

[12] Wilson, J. J., Sing, K. W.,
Lee, P. S. & Wee, A. K. S. Application of DNA barcodes in wildlife conservation in Tropical East Asia. Conserv. Biol. 30, 982–989 (2016).

[13] Budria, A. & Candolin, U. How does
human-induced environmental change influence host-parasite interactions? Parasitology 141, 462–474 (2014).

[14] Kays, R., Crofoot, M. C.,
Jetz, W. & Wikelski, M. Terrestrial animal tracking as an eye on life and planet. Science (80-.). 348, aaa2478 (2015).

[15] Cooke, S. J. et al.
Tracking animals in freshwater with electronic tags: Past, present and future. Anim. Biotelemetry 1, 1–19 (2013).

[16] Cochran, W. W. & Lord, R. D. A
Radio-Tracking System for Wild Animals. J. Wildl. Manage. 27, 9 (1963).

[17] Yasuda, M. Monitoring diversity and
abundance of mammals with camera traps: a case study on Mount Tsukuba, central Japan. Mammal Study 29, 37–46 (2004).

[18] Ishida, K., Tanoi, K. & Nakanishi, T. M.
Monitoring free-living Japanese Bush Warblers (Cettia diphone) in a most highly radiocontaminated area of Fukushima Prefecture, Japan. J. Radiat. Res. 56, i24–i28 (2015).

[19] "Wilde zwijnen hebben de tuin van Joke
omgeploegd: 'Iemand moet hier iets aan doen,'" @omroepgld, Sep. 30, 2021. https://www.gld.nl/nieuws/7385689/wilde-zwijnen-hebben-de-tuin-van-joke-omgeploegd-iemand-moet-hier-iets-aan-doen
(accessed Nov. 29, 2022).

[20] "Wolf rent achter fietser aan op De Hoge Veluwe," *@NOS*, Nov. 04, 2022. [Online]. Available: https://nos.nl/artikel/2451096-wolf-rent-achter-fietser-aan-op-de-hoge-veluwe. [Accessed: Nov. 29, 2022]

[21] "Minister wil maatschappelijke dialoog over de wolf in Nederland," *@NOS*, Nov. 09, 2022. [Online]. Available: https://nos.nl/artikel/2451779-minister-wil-maatschappelijke-dialoog-over-de-wolf-in-nederland. [Accessed: Nov. 29, 2022]

[22] M. Frith, A. Hayes, and D. House, "Policy statement FOXES IN LONDON," 2009 [Online]. Available: https://www.wildlondon.org.uk/sites/default/files/2019-07/LWT%20Policy%20-%20Foxes%20in%20London%20-%202009%2C%20Sept%202017%20rev.pdf

[23] Slobig, Z. (2015, February 4). The Wild Deer That Roam a Japanese City's Streets. WIRED. https://www.wired.com/2015/02/yoko-ishii-beyond-the-border/

[24] Magazine, S. (2021, 21 oktober). *The South African Town Where Penguins Rule*. Smithsonian Magazine. https://www.smithsonianmag.com/travel/the-south-african-town-where-penguins-rule-180978901/

[25] G. Meijer, "Hé, er loopt een zwijn door mijn dorp! (En hoe je dat voorkomt)," *destentor.nl*, Oct. 27, 2019. [Online]. Available: https://www.destentor.nl/heerde/he-er-loopt-een-zwijn-door-mijn-dorp-en-hoe-je-dat-voorkomt~ac1685bb/?referrer=https%3A%2F%2Fwww.google.com%2F&cb=c93221f2e764a6e0181f2191a739491c&auth_rd=1. [Accessed: Nov. 29, 2022]

[26] J. Selles, "Wilde zwijnen in het dorp? Zo houdt Wiljan ze uit zijn tuin in Heerde," *destentor.nl*, Oct. 19, 2019. [Online]. Available: https://www.destentor.nl/heerde/wilde-zwijnen-in-het-dorp-zo-houdt-wiljan-ze-uit-zijn-tuin-in-heerde~ab9c0a52/. [Accessed: Nov. 29, 2022]

[27] S. Church, "London foxes: urban menace or misunderstood?," *Evening Standard*, Jul. 21, 2022. [Online]. Available: https://www.standard.co.uk/insider/london-foxes-urban-population-dangerous-b1001710.html. [Accessed: Nov. 29, 2022]

[28] More, S. et al. "African swine fever in wild boar". EFSA J. 16, e05344 (2018). [Online]. Available: https://efsa.onlinelibrary.wiley.com/doi/full/10.2903/j.efsa.2018.5344

[29] Heffner, R. S. & Heffner, H. E. "Hearing in domestic pigs (Sus scrofa) and goats (Capra hircus)". Hear. Res. 48, 231–240 (1990). [Online]. Available: https://www.utoledo.edu/al/psychology/pdfs/comphearaudio/Hearing_in_Domestic_Pigs_and_Goats_HR1990.pdf

[30] Fernando Koyanagi, “ESP-NOW: WiFi With 3x More Range : 18 Steps - Instructables”. Available at: https://www.instructables.com/ESP-NOW-WiFi-With-3x-More-Range/ (Accessed: 24th January 2023)