Smart Environments Project Documentation Report

M2:SEC - Group: 08 – Project HedgeHome

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Chapter 00: Introduction

Interesting facts about the decline of the hedgehog population:

135.000 Hedgehogs die in the Netherlands in traffic accidents alone each year.

In the last ten years the hedgehog population has halved, and for this exact reason the European Hedgehog is an endangered species in the Netherlands. [1]

Main Focus of the project:

Therefore, this report focuses on the method of local hedgehog monitoring, with the use of footprint identification. Instead of the more traditional inkpad and paper technique where the hedgehog's footprints get recorded on a sheet of paper after walking over an inkpad, the proposed method evolves them with a camera and a pair of distance sensors (detecting motion).

Furthermore, with the use of weight sensors (and of course the camera itself) vital information can be gathered on the population-size, and overall well-being of the hedgehog array. This information can be used to formulate new or improve policies on a local level regarding hedgehog-safety.

In addition to this, the hedgehogs' habitat is increased, since the tunnels provide a means for them to be able to move from garden to garden, resulting in less hedgehogs crossing the roads.

Chapter 01: Literature Review

01 - Wildlife Insights: Saving Biodiversity with Tech and AI

It is said that about 20% of biodiversity could be lost if the right measures will not be taken. Experts try to conserve these species before it is too late. The camera traps used for gathering information create enormous amounts of data (about 115.000 images per camera each month), which cannot be processed by a human being in a reasonable timeframe. That is why Google is working on a cloud-based platform which uses AI to classify images in relation to the animals shown in them. [2]

02 - Drones and wildlife monitoring - is it a good idea?

Wildlife monitoring fieldwork can be quite inconvenient for a human being due to the number of tools one requires to get the job done properly. Fortunately, drones can complete the same task with greater efficiency and accuracy. Advantages of using drone technology in wildlife monitoring include cost efficiency, safety, reliability, and larger data samples. Although the question may arise whether the drones disturb the animals, multiple studies show that the drones do not have any harmful impact on wildlife or their daily routines. Moreover, in some cases they can be used to actively guide a herd of animals to a safer location, thus preventing unwanted wildlife encounters by the public. [3]

03 - AWC trials new drone technology for monitoring wildlife

The Australian Wildlife Conservancy (AWC for short) is currently in the works of mapping out small mammals such as mice species in Australia. One of the tools that is helping them in this process is a drone. The drones are equipped with not only regular cameras but also infra-red and thermal sensors for a better understanding of the wildlife it is set out to monitor. Since each animal has a specific heat signature, it is rather convenient to combine these sensors for a more accurate representation. [4]

04 - Endangered African Wildlife Monitoring Explained

Wildlife ACT focuses on monitoring the wildlife in a smaller area in Africa. They check on the animals daily to make sure they are in good health. The main benefit of monitoring provides us a better understanding of these animals, this includes the tracking of movement patterns, population demographics, disease outbreaks and poaching incidents. Tools such as GPS collars are used to track animals individually, but also more conventional techniques like camera traps are helping them in the process. [5]

05 - Methods of Observation

This paper discusses the various methods and criteria used to record and evaluate data. It explores multiple methods of data-capture ranging from modern (video-recordings) to old-school (paper-recording). It also highlights the importance of deciding on an appropriate judging-criteria, for example an accurate and relevant frequency. Another topic it mentions is the effect observation might have on the observed. [6]

06 - WildCam Observations

This article talks about how students can evaluate and discuss wildlife with their peers. It had given the students information based on a livestream of animals and they could give criteria and then discuss it through a given worksheet. The students could then take the information with them or extend it if they wished to do so. [7]

07 - Nocturnal Animals

This article gives us insight into how one can attract and observe nocturnal animals. One can do so through various methods discussed in the article and more importantly it also does so in an unharmful and friendly way towards the animals. It doesn't go into much detail on how to observe and attract these animals, but the general idea and small examples are given. [8]

08 - Secondary Signs

This paper discusses multiple methods of identifying and observing various animals found in the wild. This paper goes into great depth about the typical living spaces of various animals one may find during their observations. Different types of the observed animals are discussed and how one can lure animals in an unharmful way, for observational needs. For example, one may use marks or damage done to the surrounding environment to detect if (and what) animals have recently been present in the site. Bones and waste are also a great indicator of what may be found in the area. Also, if fellow animals or team members show signs of allergies at the site that can also be a useful indicator. And lastly nests and feeding signs are quite useful in detecting which animals may be present at the site of interest. [9]

09 - Deep learning to identify birds

The study tests how to use deep learning to identify different bird species. In the study they train a network to recognise the different bird species by using labelled wild birds and captive birds. Pictures are taken from different angles and a few birds are selected for the sample to train the program. The program can identify the birds from the sample space when given new pictures containing them, even more when a distortion is added to make it look more like the pictures from the training/validating process. [10]

10 - Using tourist photographs to monitor wildlife population

This source investigates if it is possible to use tourists as a means of monitoring wildlife. The study uses photographs taken by tourists to identify species and numbers of animals in certain heavily visited wildlife tourism spots. By using the tourist pictures, it is cost-effective. The researchers do so by asking tourists from a group tour if they can use their pictures. The researcher gives the group 2 GPS trackers which are also time linked, so the researchers know when and where the picture is taken. At the beginning of each tour the tourist cameras are calibrated with the GPS devices. After the data is collected, one researcher will look at the photos and identify species. [11]

11 - Using real-time data to monitor animals

The paper focuses on monitoring animals in real-time using equipment mounted on to the animal, the data gathered by the equipment is sent to the cloud and analysed. The paper talks about using cloud technology to analyse and monitor animal behaviour, as an example the researchers monitored a group of elephants. By gathering the location data from the elephants, they were able to predict the next location where the elephant was going through the use of an algorithm. They used data to set up a digital border around a certain area of farmland, if the sensor on the animal crossed the border a team would be sent to relocate the animal away from the area without harming it. [12]

12 - Drones vs. manual counting

The study analyses the accuracy of counting with an algorithm against counting manually. In the research a drone is used to take pictures from a colony. The drone flies directly above the colony and moves upwards while taking pictures, these pictures are made using a high-quality camera. The pictures taken are analysed using an algorithm to get the numbers of animals. A group of ecologists counted the animals from 40m away from the ground level. When comparing the drone numbers to the numbers from the ground observation the drone with the algorithm had a higher accuracy. [13]

13 - The German bee monitoring project

This is a paper about a four yearlong study, monitoring over 1200 bee colonies, and their losses over the winter period. It was found that the Varroa destructor mite plays a key role in the loss during the winter as well as viral infections, old queens and colony weakness. Bee samples were collected by a scientist/inspector twice a year, then the population and hive quality were looked over. [14]

14 - Long-Term Monitoring of Dzanga Bai Forest Elephants: Forest Clearing Use Patterns

This is a paper about the increasingly threatened species of forest elephant (Loxodonta cyclotis). It is a long-time study over 20 years monitoring the visitation patterns and population, providing information about the social behaviour and threats to forest elephants. Results show that the population in males decreased about 10% while the population in females increased. The visitation patterns which were observed have shown to be highly variable for each individual, varying from monthly to yearly visitations. They have also shown themselves to be more nocturnal when threatened by human-induced development activities. [15]

15 - Fathoming Sea turtles: monitoring strategy evaluation to improve conservation status assessments

This paper is about a simulation-based tool, evaluating monitoring strategies to test the correlation between data and accuracy, using the green turtle. During the study the monitoring strategy evaluation (MoSE) is proven to be an important tool for analysing through simulation by demonstrating the potential errors. MoSE can be used to provide advice for how to achieve the most accurate data. For example, the model recommends at least 10 to 20 years of monitoring. MoSE has the potential to help already existing monitoring approaches for sea turtles or species to provide more accuracy. [16]

16 - A comparison of cost and quality of three methods for estimating density for wild pig

This paper compares three common monitoring strategies on their cost efficiency and accuracy using the wild pig as a case study. They compared Fecal DNA sampling, camera sampling and removal sampling, providing a decision tree on which monitoring method to use for different cases. [17]

17 - The pitfalls of wildlife camera trapping

This paper is about multiple flaws of monitoring wildlife using cameras in Australia. These pitfalls are rarely mentioned in research according to this paper. Some pitfalls that are rarely discussed are the camera detection system itself(accuracy of the system for example), the settings of the camera traps and effects of the cameras on the behaviour of animals. These factors should be further studied to determine the influence on the interpretation and analysis of the data. [18] [19]

18 - Bias in Aerial Survey

This paper talks about the accuracy of aerial counting of animals, and talks about how many it misses, the biases of this method, and how to eliminate them. It talks about how aerial counting surveys often do use a standard error, but still assumes that all

animals presents were counted. With this approach the changes in the size of a population can be correctly estimated, but it will be impossible to know what the exact population is. When looking at the change in population size and standardizing monitoring methods, biases can be eliminated or held constant. [20]

19 - Methods for wildlife monitoring in tropical forests

This paper about the good and bad things of 3 types of wildlife monitoring, these are humans (visual or acoustic), camera traps, or passive acoustic sensors. Trade-offs between these methods are coverage, accuracy, technical expertise, when people are in the field doing visual and acoustic monitoring, how sure one can be that it is a certain animal, how many animals do not get heard/seen etc. and the costs, since a lot of man hours are expensive. To determine what type of monitoring can best be used 4 questions should be asked: "(1) What are the target species? ; (2) Which population metrics are desirable and attainable?; (3) What expertise, tools, and effort are required for species identification?; and (4) Which financial and human resources are required for data collection and processing" [21]

20 - Restoring Connectivity in Landscapes Fragmented by Major Roads

This paper is an example of the importance of wildlife monitoring. The habitat of; among other animals; tree-dwelling mammals, were fragmented by construction of manmade objects (such as roads and bridges). To re-join the habitat of these animals, wooden poles with ropes between them were placed to bridge the obstructions within the habitat. To monitor if the tree-dwelling mammals used these poles, hair and camera traps were used. Without these wildlife monitoring traps the effect of these poles would have been unknown. [22]

Chapter 02: Identification of General Problems and Challenges

01 - Varroa destructor mites play a key role in the loss of bee colonies during the winter as well as viral infections, old queens and colony weakness. [14] [23] [24]

02 - About 20% of biodiversity could be lost if the right measures will not be taken in the next couple of weeks. [2]

03 - The Dzanga Bai Forest Elephants are an increasingly threatened species (their population is rapidly decreasing). There is not much information out there about the species in total. [15] [11]

04 - Elephant colonies in Africa and Asia are endangered by poaching and habitat loss. [25]

05 - Nocturnal animals, specifically hedgehogs, are on the red list in the Netherlands. They often get killed by cars or die due to starvation. They sometimes go out of their winter sleep too early because of high temperatures in the winter, in which during this season they do not have enough fat reserves and (almost) no food available. [26] [27]

06 - Large carnivores in northern Spain are endangered due to human induced development activities and natural factors. [28]

07 - Invasive wild pigs in South Carolina, USA are causing economic damage to agriculture. It has also been found that they are linked to the extinction of local species. Therefore, it is important to monitor them and oversee this invasive species. [17] [13]

08 - Whales and their territory are endangered because of pollution in the sea, harm caused by fishing gear and collisions with freight ships. [29]

Chapter 03: Identification of Relevant Problems

01 - Wolf tracking / monitoring:

Wolves have made their return in the Netherlands, which might excite some nature fans, but irritates and interferes with farmers. Some of the local governments and nature reserves are getting more and more worried about the situation. Wolves currently do not have a natural predator in the Netherlands, and since its introduction to the Dutch nature it has become tamer, which may be good on one hand, but it also means that they are coming closer and closer to people. Therefore, it could help to monitor them so farmers can protect their animals and people can be alerted in advance when they must watch out for them.

02 - Green-turtle monitoring:

Many turtles' lives are endangered due to them consuming plastic floating around in our oceans. In certain parts of the world, they are also hunted for trade, and accidentally caught during fishing. A great contributor to their endangerment is that of their habitat loss, for example coastal development, which not only destroys their living areas, but also causes pollution. Furthermore, turtle eggs are considered a delicacy in many parts of the world.

In order to monitor these turtles, trackers are being attached to their backs. These trackers are unharmful and eventually detach from them. Green-turtles can dive down up to 960 ft (290 m) into the ocean. [30] [31] [32] [13] [14] [15]

03 - Loss of bee colonies in the wintertime:

Western honeybees are one of the most important pollinators in agriculture. They are responsible for the pollination of different types of berries and nuts (amongst other plants). The demand for pollination in agriculture is increasing year-by-year. And with the decline of honeybee hives (especially during the wintertime) it is necessary to monitor them to be able to prevent their extinction and decrease the consequent damages. [24] [23] [14] [33]

04 - Hedgehog (endangered species) monitoring:

It is quite important to monitor the hedgehog population, since they are protected animals in the Netherlands. The number of hedgehogs keeps declining year after year, thus making them a “protected fauna species”. Hedgehogs are small nocturnal animals meaning they move around mostly at night. Their spikes protect them from predators; however, these spikes aren’t built for the modern world. If they get run

over by cars, they have quite a low chance of survival. Our modern gardens aren't that safe for them either since these may contain steep edges of ponds and robotic lawnmowers. Due to their nocturnal nature, it is quite hard to monitor them, but that does not mean they should be neglected, since they get rid of harmful bugs and insects. Apart from the darkness being a challenge they also like to move around quite a lot, going through shrubs and across different backyards. All the above-mentioned information shows why it is so important to monitor them and stop their population from further shrinking. [34]

05 – African elephant monitoring:

Elephants lose their habitat because humans take the land for farming and infrastructural development. This reduces their habitat and disconnects the parts of land that they still have. [35] Furthermore, this increases the number of human-elephant conflicts. A lot of conflicts happen when elephants go "crop raiding". Eating food of farmers. This happens more often because the elephant's habitat and the farms are getting closer to each other, due to the expansion of farms. This is one reason as to why elephants and people get killed by each other. This happens more in Asia than in Africa. [36] [37] [38]The number of African forest elephants has decreased 86% over 31 years, the savanna elephant is reduced in numbers by 60% in 50 years. This is largely because of poachers that shoot elephants for their ivory and often selling it, 90% of the profits ultimately go towards the funding of jihadist rebels. [25]

Chapter 04: Problem Selection and Motivation

In the end Hedgehog monitoring was chosen as the theme of the project for the following reason:

It is quite important that we start monitoring the hedgehog, since the population of them in the Netherlands is rapidly declining. In the last ten years the hedgehog population has halved, and thus are on the red list of the Dutch government, which means they are a protected species.

The European hedgehog (Erinaceus europaeus) falls under the third appendix of the Bern-convention, which means there are certain rules and regulations guarding them, but they are not sufficient enough currently. [39] [34]

01 - General Information Relevant to the Design Process

The hedgehog is a carnivorous mammal that lives in not only Africa, but also the Middle East, Europe, Central Asia and New Zealand. [40] [41] [42]They vary in size from 13 to 31 centimetres and vary in weight from 400 grams to 1.5 kilograms. [42] [43] They get their name from rooting though hedges searching for food, while making hoglike grunts. When attacked or asleep during the day they roll up into a ball and spread their spines. At night they wake up and go searching for food. [42] [1]

In a cold climate such as Europe, hedgehogs usually hibernate from October / November until March / April, however during mild winters hedgehogs might not go into hibernation until November / December. [42] [43] They wake up every 7 - 11 days. When they get too cold, they might look for a new place to sleep, but usually they stay where they originally set camp. [44] During hibernation they lose anywhere from 15% to 40% of their weight. [45] In more temperate locations hedgehogs remain active all year. In deserts, hedgehogs do not go into hibernation, but into aestivation (this is when they sleep through heat and drought). This is not applicable to our situation so no more time will be invested in this. [42] [39] [46]

02 - Which threats they face

Hedgehogs face a lot of threats in our modern world. Cars and road traffic provide a big threat to hedgehogs. Our gardens aren't safe for them either: ponds, bonfires, netting and pets. For example, if a hedgehog falls into a pool or pond it will drown, they can also get stuck in netting or get too close to a fire. Pets can also traumatize and hurt hedgehogs: some of these injuries can even be fatal. And pesticides, chemicals, and animal traps provide a threat for the hedgehog as well. Climate change

is also quite a big threat for them: More and more hedgehogs are dying of dehydration due to higher temperatures; Drought threatens one of the hedgehogs' biggest source of food: insects; Temperature increases in the winter distort the hibernation period of the hedgehogs; And their activities increase earlier while there is not enough food available for them to survive. [47] [48] [49] [50] [51]

03 - Why we should protect them

Amongst all the above-mentioned reasons, hedgehogs are gardeners' favourite bio-friendly slug repellents. They feed on snails, slugs, and other types of pests, removing them from vegetable patches and gardens in general.

Also, they are an indicator species, meaning that monitoring them gives us an indication about the health of the ecosystem. [47] [48] [38] [50] [51]

Chapter 05: Potential Solutions [34]

01 - Spotlighting

Spotlighting is useful for not only detecting the presence of -, but also the number of hedgehogs. Since these animals are nocturnal the studies are conducted during the night-time.

The main premise of this method is that the field worker is going around with a flashlight looking for the hedgehogs at night. The use of a torch along the ground or known tracks of these creatures is helpful for our case since humans have a lot of difficulty seeing at night.

Other difficulties may arise as well while conducting these surveys: due to their night-time habits it can be fatiguing for surveyors; also, the foliage of the area contributes a lot to the visibility of these animals, i.e., tall grass blocks more than short grass.

Fortunately, these studies are low in effort as only a torch is required and in some cases a license.

02 - Footprint Identification

Hedgehogs have very distinct footprints of which this method is taking advantage of. With the use of simple tunnels one can conclude about the presence of the hedgehogs. The tunnels can either be bought for about £100 (≈ 115,83€) or be self-made. They have a plastic covering and the insides are laid out with DIN A4 paper, ink and commercially bought hedgehog food. They can be left out for about five days.

When a hedgehog is now walking through the tunnel, they will leave their unique footprints on the paper which can be identified.

The advantage of this method lies in the simplicity. The tunnels can be checked at any time of the day or night, so there are no restrictions. The checking itself is also simple and does not take much time. Another advantage is that a license is not needed since the hedgehogs are not being held captive and can pass through the tunnels.

Some disadvantages of this method are that it might take some time until a hedgehog encounters the tunnel, as well as that the footprint identification might go wrong, but those are hypothetical. Another big disadvantage is that the data collected only shows the absence or presence of the hedgehogs and nothing more.

03 - Radio tracking

The use of radio-tracking technology to track hedgehogs has some negative and positive benefits. By using a transmitter to track a hedgehog they can be tracked during day and night with a high grade of precision depending on what type of

equipment is in use. Also, it allows for monitoring of multiple hedgehogs at the same time in a remote location.

However, this also comes with a negative effect. Because the device is always active - there is a lot of data gathered, which can be hard to process. The transmitters themselves are also quite expensive and need additional infrastructure to work. Which makes the operating cost quite high in comparison to other methods. The use of trackers is not always allowed and using one may require a permit.

04 - Thermal imaging

Using thermal imaging could be a great tool when monitoring nocturnal animals, since they are mostly active at night when vision conditions are not ideal. The hedgehog (as well as almost every other animal species) has a unique heat signature, which can be detected and recognised. In ideal conditions - meaning open environments, without much obstruction - hedgehogs can be detected from a distance of 70 meters.

The two main methods in thermal imaging that could be utilized, are stationary monitoring and surveying.

In stationary monitoring (as the name suggests) the camera/sensor is mounted at a fixed location and can be accessed remotely. This has the benefit of being able to automatically detect the presence of hedgehogs using image recognition. Since it is much less labour intensive, and also it costs less than the other method. Although it must be noted that this is still quite an expensive way of monitoring wildlife, since the price of one camera can range anywhere from €600 to €8000.

Method number two involves live surveying (much like spotlighting) with the added benefit that this method does not disturb the animals. But as one may imagine this is extremely labour intensive and does raise a concern for the safety of the surveyors, since as mentioned previously the conditions are not ideal.

05 - Live trapping

Live trapping can be used as a monitoring tool, as well as a tool for capturing hedgehogs to mark them and release them. This could be handy for radio tracking or even for marking hedgehogs to identify them while spotlighting. Live traps are inexpensive to set up, however it does cost a lot in manual labour. As a result of hedgehogs being active during night-time, traps should be checked every morning, and if needed, the captured hedgehogs need to be marked. In the evening bait should be placed in the traps. To monitor a small area accurately (a couple 1000 square meters), around 20 traps should be placed down.

Even if no bait was set, a lot of other animals will walk in the trap (called bycatching). This is quite a big problem; cats, rabbits or rats could all walk in the trap, disabling the trap for the rest of the night. Furthermore, licenses are usually needed to legally

trap hedgehogs. On top of that, capture rates tend to be low for hedgehogs and can fail to detect the presence of them. [52] Even though there is no physical harm done to hedgehogs, live trapping can be seen as unethical, as the captured animals can experience stress of not being able to leave and/or having no water and food available to them.

With that being said live trapping is arguably a harmless way of capturing and marking hedgehogs. However, it is not an accurate method of monitoring. Depending on the size of the hedgehog population in a certain area, it is less manual labour to tag hedgehogs using live trapping than it is using spotlighting.

06 - Camera traps

The main premise of using camera traps is that by mounting multiple cameras in a finite area we can collect data remotely without the need for human labour. The cameras take photos of any animal which passes by. These photos can be processed by either a human or by using computer vision.

Benefits include: the fact that it does not disturb the animals and depending on the placement of the cameras it can be used to determine presence, approximate density, or even calculate the relative index of abundance.

Disadvantages include three major setbacks: First of all, human maintenance is required every couple of days to ensure that the batteries are charged, the memory sticks are changed out, and the enclosures are still securely mounted. Secondly, it can become expensive quickly when using multiple cameras, since a single camera can cost anywhere from €120 to €350. Lastly it is worth mentioning that this method cannot be used for monitoring at night-time.

Chapter 06: Solution Selection

The chosen method: Footprint recognition

As mentioned previously, hedgehogs have very distinct footprints. They are relatively easy to distinguish / identify. In addition to this reason, footprint recognition is one of the few methods which does not require a license to be carried out.

The proposed solution consists of tunnels between (or near) fences in urban areas. The product focuses on everyday consumers for even wider-spread data collection. For this reason, the design relies on people installing these tunnels in-between (or near) their gardens in urban areas, acting as not only a safe and free path for hedgehogs to take but also as a data-collection node.

In contrast to the proposed solution (found in the above-mentioned papers), our method relies on the use of a camera as a means of footprint recognition, with the possibility of adding a weight sensor to be able to monitor the health of a hedgehog (owing to the fact that that metric is the most commonly used and fastest method of determining whether they are healthy or not).

Our team believes this is the best option given the considerations of: cost effectiveness, data collection / analysis, smart environmental restrictions, and of course manual labour.

An important aspect to mention about the method

During the ideation process the idea arose to lure the animal with some sort of bait into the tunnel, since it can be bought in most pet stores around the city. In the end our team decided against it to prevent overestimating the number of hedgehogs in the specific neighbourhood and to obtain accurate results about the population with our data.

Chapter 07 – Methodology

Basic Scenario:

In our basic scenario, the team makes a hedgehog tunnel that can be installed through fences in backyards. When a hedgehog walks through the tunnel, a distance sensor gets triggered which actuates a camera that is underneath the hedgehog. This camera takes a picture of the footprint(s) of the hedgehog. Everything is connected to - and locally stored on a Raspberry Pi. Using these pictures, validation can take place by checking if the footprints match those of hedgehogs, by a human. On both sides of the fences custom face plates can be installed to the liking of the users (noting that the two different consumers on the two sides of the fence, might not fancy the same face plate design). The basic look without the face plates is a simple black box.

Ambitious Scenario:

For the ambitious scenario multiple elements can be added to make the basic scenario more complex. Footprint recognition can be done by a trained AI model using image recognition. The result can be stored locally, and (if time allows) it can be uploaded to a server. In addition to all of that, a weight sensor can be added to check the weight of the hedgehog. This data can be used to get an indication of how healthy the hedgehog is.

On top of this, using the locational data of the tunnel, directionality can be added. If a hedgehog walks through the tunnel towards a road, a separate warning system can be triggered.

Final Product Extract:

The proposed method for footprint identification of hedgehogs relies on autonomy (thus placing it in the realms of a smart environment). The proposed solution is a tunnel, which can be installed between fences in neighbourhoods. This not only provides a platform for housing the sensors, but also allows hedgehogs to move around more freely in a neighbourhood. This way we are not only monitoring the hedgehogs but also helping them sustain their population.

Final Product Design - Casing:

Considering the fact that the tunnel will be placed outdoors, it is a necessity for it to withstand the elements. This means that a waterproofing-layer and a sturdy construction is required. The bottom half should be made extra-waterproof as this

part will be placed under ground-level. This is achieved with the use of water-proof lacquer and silicon around the seams.

The product focuses on everyday consumers for even wider-spread data collection. For this reason, the design relies on people installing the tunnels in between their gardens themselves.

After taking into consideration the sizes of hedgehogs, the final design of the enclosure was fabricated. For easy installation the section under ground-level was made as shallow as possible, which minimises the digging required for installation.

Final Product Design – Front Plates:

The use of magnetically attachable and detachable front plates on both sides of the tunnel allows matching of the tunnel to its surroundings and the preference of the consumers (having the ability of the two sides of the tunnel to be different). For demonstrational purposes the team decided to make two designs of the front plates. One of which is more minimalistic and more in line with nature for those who like it and the other one is more intricate, showing the front side of typical houses one would see in Amsterdam (this one is also much bigger). The addition of the interchangeable front plates makes it more customisable for the end user(s). Families can set up their tunnel and have fun with decorating their gardens in different ways. It can be a fun activity for the whole family (especially for families with smaller kids, where it can be used as a conversation starter for biology and environmental awareness). Of course, it is also possible to leave the tunnel as is and not use the front plates.

Final Product Design – Hardware / Software:

With a distance sensor and a camera, our team hopes to capture data about the animal which enters the tunnel. Once the distance sensor is triggered by a moving object in comparison to the static wall, the camera actuates and will take a picture. The camera is placed on the bottom, meaning when a sensor is triggered a photo of the footprints of the animal entering will be taken. The process of validation can be done by an AI. A picture gets stored and in a case that would require human intervention to process the data, it is sent to a database for easy access. Also, by using two distance sensors, (one on each side of the entrance) we are also able to determine the direction of which the animal came from and is heading to.

The use of weight sensors is also implemented, to determine if a hedgehog's weight is in a healthy range or not. However, these weight sensors need to be calibrated, for it to be able to provide accurate readings. The accurate result is calculated by adding the readings of the two weight sensors, since mass distributes on the capture-plate.

By linking the weight data, the image analysis can be performed on how many hedgehogs have passed through the tunnel and whether they are healthy. By using multiple nodes this information can give an insight into where the hedgehog

population is the highest, thus providing us with a heatmap for the hedgehogs. We can draw conclusions from this and modify less visited areas to make them more suitable for hedgehogs. The data can also be used to inform humans in the area that there are many hedgehogs roaming around, and even influence local developments.

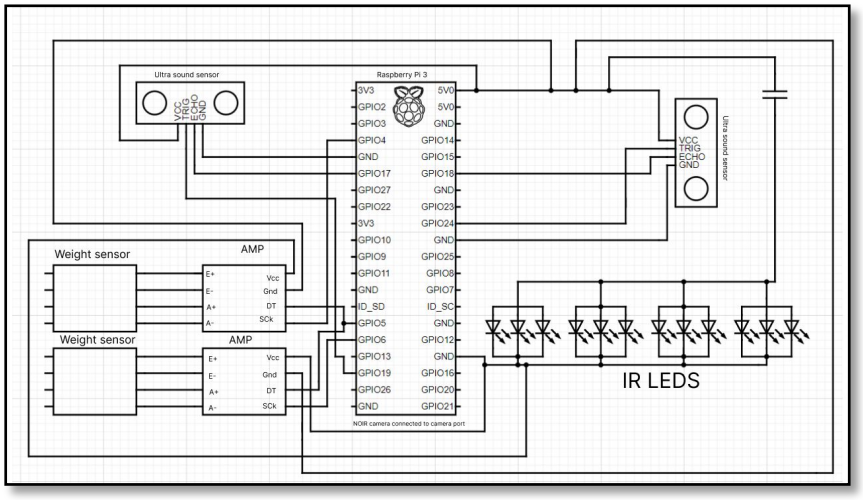

Fig. 1: Diagram of Final Circuitry

A website (hosted locally) makes the project not only useful, but also fun for the users. The website itself is a dashboard that displays all activity happening in the tunnel, with meaningful graphs and data visualisations. We have also implemented a live feed for anyone interested in looking into what the tunnel sees.

Usually, wireless sensor nodes require batteries, but we decided against it for a more user-friendly application. The tunnel can be powered via a normal AC power socket. As far as communication is concerned, the project uses the local Wi-Fi network of the customers household, since it is reliable, and allows us to host the local website as well. (An active Wi-Fi connection is required, from which you can get the IP-address of the system).

Our team believes this is the best option considering: cost effectiveness, data collection / analysis, smart environmental restrictions and of course manual labour.

Weekly Time Plan:

Task	Due Date
Brainstorming / Idea Generation	Week 50
Casing Design	Week 51
Circuitry Design	Week 51
Software Design	Week 51
Brading (logo design, product sketches, naming)	Week 51
Inventory Management / Ordering Parts	Week 51
3D Modelling + Fabrication files	Week 01
Casing Assembly	Week 03
Circuitry Assembly	Week 03
Software Development	Week 03
Final Validation + Report	Week 03

Task Assignment:

Task	Allocated Person
Brainstorming / Idea Generation	All Members
Casing Design	Jarne + Rutger
Circuitry Design	Jarne + Patrik
Software Design	Jalen
3D Modelling + Fabrication files	Patrik + Marie
Brading (logo design, naming)	Marie
Casing Assembly	Rutger + Jarne
Circuitry Assembly	Jalen + Patrik
Software Development	Jalen
Inventory management / Part ordering	Patrik
Final Validation + Report	All members

Chapter 08 – Validation

In this section our proposed method is being tested. Because it was not possible for us to test the tunnel in the wildlife with real hedgehogs, we decided to test our tunnel with a 3D-printed hedgehog model. The data resulting out of the test with the 3D-printed hedgehog should be applicable to the real world with living hedgehogs. The only thing we cannot validate due to the chosen method is if we are able to lure the animal into the tunnel.

From our tests the AI we used to detect has a nearly 50% accuracy rate of detecting the correct footprints. It used to be 30%, so we had figure out what was causing such a low accuracy rating. The main issue lied within the edge detection, since the 3D printed model was a solid white colour. We painted the legs red for a higher contrast and that significantly increased the rate of accuracy (given the increased contrast). Given a higher training set and perhaps using a different technique may provide better results.

We're also using real-time sockets for streaming the camera to the front-end and database. Disconnected sockets are properly disposed of, and the living sockets are updated accordingly (say if data is added/removed or if the camera is (dis)connected).

The entry points of the box are also 100% accurate to which point the animal had entered, once the animal leaves the platform, we listen for an entry port again (since it is possible the hog can move back and forth, which would mean that it entered multiple times which is most likely not true).

We're also using multithreading (for the camera, ultrasound sensors, web server and weight sensor). However, synchronization is only ensured where necessary such as the entry points, since the output varies a lot between which sensor is set to a high output, we then check each entry point alternatively in a joint mode (A then B then A then B).

Chapter 09 – Results and conclusion

All things considered the project worked out well and we are content with the outcome. The construction of the product is sturdy and easy to install. All sensors are working properly, and the image recognition model is able to detect the test-animal. The design of the locally hosted website with the live-streaming capabilities and data representations is usable and inviting, and the backend with the database storage is also working fine.

With that being said, there are certain aspects of our product which would be nice to improve upon for it to be able to claim it's space as a commercial product. Mainly speaking of the margin of error the sensors are working with. Due to the budget limitations the project needed to compromise on the quality of the parts, which lead to them being lower quality, producing not 100% accurate readings. This means the margin of error on them is a bit bigger than would be appropriate.

In the evaluation phase a test-animal was being used for training and evaluating the AI model. The team tried to make sure to use the most accurate (true-to-life) 3D model, but of course it is not a real animal. This decision has been made after considering training the model in the wild (with living animals), but due to the lack of time and more importantly, knowledge (since labelling data collected in the wild does require high levels of biological expertise) this was discarded.

Furthermore, we did not manage to make the tunnel 100% waterproof. It is only a prototype, and the front plate is also not waterproof. Installing a waterproof layer was not possible due to time, but it would also be out of our budget, which is why we decided to go for laser-cut wood. A more appropriate material would be laser-cut acrylic, but that would not have fit in our budget.

Also due to it being the final prototype of the project, the electronical connections are partially being made with the use of breadboards. Where possible soldered components on perf boards were used, but for easy disassembly the team opted for the hybrid solution.

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