UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

ANIMAL ROAD CROSSINGS (ARC)

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Chapter 0: Introduction

<To be prepared the 5th to 6th week>

The following project has been carried out by seven first year Creative Technology students. This project is taking place during the second module of the study programme and is a part of the Smart Environment course of the studies.

The most used method for warning drivers that wildlife might be crossing is putting a warning sign on the side of the road. However, the effectiveness of such a warning system has proven to be minimal. To avoid any unnecessary roadkill, a driver is forced to drive at slower speed and be more attentive for an unknown/specified distance. This results in drivers not willing to be more careful and driving as usual, therefore increasing the chance of a roadkill incident. This phenomenon relates to the fact that in Europe alone, around 29 mammals are killed annually in roadkill incidents [24].

In this report various problems regarding wildlife tracking are researched. A solution is found and produced for one of them: How to increase animal and driver safety at places where animals frequently cross the road. The final solution agreed upon is to design and implement an improved warning system that would notify passing drivers if any animal activity is detected nearby the road. This system would use PIR sensors (Passive Infrared sensors – a compact, affordable, and low-power motion detecting sensor) directed towards the area outside a road/highway. These sensors would then activate nearby warning lights, resulting in a real-time warning system. This system would be more effective than a traditional warning sign, allowing drivers to drive as usual if there are no warning lights going off.

Chapter 1: Literature Review

<To be prepared the 1st to 2nd week>

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

You should add references properly, following the IEEE style. An example reference is shown here [1]. *The list of references (bibliography) is at the end of this document.*

The following table lists 20 relevant papers that our project group collectively managed to find:

Reference number(s)	Topic(s)	Summary
[1], [2]	Monitoring system called "BearCam" Evolution of wildlife monitoring sensing networks.	One instance of a monitoring system is BearCam [1]. This camera system, deployed in 2015, can capture footage of bears in the harsh climate conditions of the Arctic circle. This is made possible by implementing an algorithm that can process motion information to detect a bear's presence and successfully capture it. In a similar matter, the paper presented by Dyo, et al. [2] discussed the evolution of wildlife sensing networks. The study consists of the findings of a one-year report analysing the social co-location patterns of European badgers. The report touches on the various stages the implemented network had to undergo to become successful and sustainable, from cost management to hardware and software optimization.
[3], [4]	GPS tracker that does not require internet connectivity. Combination of forest fire detection systems with wildlife monitoring systems.	An example of a monitoring network [3] depicts a GPS tracking system, that works using LoRaWAN. LoRaWAN is a LPWAN (Low-power wide-area network) protocol designed to connect battery operated 'things' to the internet in regional, national, or global networks), resulting in a tracker that works without the use of Wi-Fi or cellular connectivity. The main parts of this project include an Arduino Uno board, a LoRa shield and a LoRa gateway (in the video, a Dragino gateway is used). When used in conjunction, a system that constantly sends the longitude and latitude values to the gateway can be implemented. More examples of this can be found in paper [4] that discusses the possibility of combining forest fire detection systems with wildlife monitoring systems to observe the changes in animal behaviour in case of a forest fire.
[5], [6]	Wildlife monitoring techniques.	An example of monitoring techniques can be found in paper [5]. A discussion about different monitoring techniques for distinct species and the protocols that

	Monitoring both small and large populations of species.	need to be obeyed so as not to endanger or hurt the species is present. The paper depicts techniques, methods, and examples related to the methods of monitoring to better understand how they work. The paper [6] touches upon the importance of monitoring and controlling both small and large populations of species to be able to better assess and protect biodiversity. It aims to evaluate different methods of monitoring large wild animal populations. Different methods allow us to determine the size of a population without affecting the animals and without significant financial costs. The paper also measures the accuracy and conditions of each method/tool.
[7]	Wildlife monitoring methods	Projects in the western United States regarding riparian restoration have not implemented monitoring plans and thus missed opportunities to conserve them. Collecting data from monitoring wildlife assists policymakers, stakeholders, and researchers in allocating time and resources for monitoring methods. The paper [7] covers several methods, such as GPS devices, mark-recapture, faecal DNA surveying, circular plot point counts, mist-net transects and bird-banding, transect counts, and nest monitoring.
[8], [9]	Four distinct types of monitoring systems to enhance biodiversity data collection. Usage of drones in wildlife monitoring.	Another paper, presented by Stephenson [8], discusses the lessons learned from applying four distinct monitoring system types to enhance biodiversity data collection. These include satellite-based remote sensing, cameras, acoustic recording systems, and environmental DNA. This author concludes that although these techniques have multiple applications, their excessive cost and low accessibility requires them to be used along with more traditional observer-based methods. These problems are crucial to address, as mentioned in a TedTalk [9] carried out by Kitso Epema, an aerospace engineer based in TU Delft. His focus was pointing out the rate at which rhinos are being hunted for their horns. He pointed out that at this rate, rhinos will become extinct in 10 years. To combat this, he points out that the usage of drones could be the way to save not only rhinos, but other species too.
[10], [11]	Unmanned Aerial Vehicles (UAVs) and artificial intelligence revolutionizing	This paper [10] is about a drone and an AI system that a group of researchers created that estimates specie population sizes more accurately. An example of the usage of similar techniques can be found in wireless

	wildlife monitoring and conservation. Wireless collection/sending of data	sensing networks, which can be used to better understand animal behaviour in correlation to their environment. This is achieved by combining GPS and satellite data, as described in the paper "Monitoring Animal Behaviour and Environmental Interactions. Using Wireless Sensor Networks, GPS Collars and Satellite Remote Sensing" [11]. The described WSN uses mobile nodes that can collect data and be given a position through GPS or proximity sensors, and static nodes that can collect data from the mobile nodes and send it away.
[12], [13], [14]	Animal disturbance due to human infrastructure. Usage of cameras in wildlife monitoring, the automation of them.	A significant wildlife corridor in Calgary, Canada, may be disturbed by a new highway bridge. Locals were against the building of the bridge as the traffic could scare animals away. The Miistakis Institute will use cameras to see how the new bridge affects wildlife behaviour, so in the future, the effects of infrastructure on wildlife can be observed before building. [12] To try and counteract this type of issue, some projects like "Where is my Deer?" [13] utilize a motion detection camera in combination with AI to detect deer. This article describes the current ways of wildlife monitoring as an introduction. The goal is to improve the accuracy of the camera system by automating the detection of deer. This is an excellent example of autonomy and can be helpful for our project as it shows the components of the sensor. Similarly, the paper [14] elaborates deep learning models to identify animals captured on wildlife cameras.
[15]	Usage of time-of-flight of an acoustic signal in wildlife monitoring.	The calibration of a sensor network can be tricky, as GPS is not always available or accurate enough. An elaborated solution is present in the article "Automated Wildlife Monitoring Using Self-Configuring Sensor Networks Deployed in Natural Habitats" [15]. The solution uses the time-of-flight of an acoustic signal to determine the relative location of other nodes in the network. A similar method can then be used to position a source of a sound, like an animal.
[16], [17]	Usage of AI in sensing networks. Deep Learning model YOLOv5	It is possible to use AI to help improve sensing networks and bird counting [16]. When people count birds, the process being accurate is not guaranteed. By gathering many photos of flocks of birds and leveraging the capabilities of AI, more accurate counting can be further improved. Also, the current

		Deep Learning model YOLOv5 [17] is being used to detect animals. A study has sought to see how effective the performance was. Successful detection of several mammals in forests with camera traps occurred. The results proved promising. All of this might be something to consider using for our project for mammal or bird detection.
[18]	Tropical rainforest monitoring	Continuing the topic of tropical rainforests, this paper [18] discusses the different methods/approaches related to the monitoring of tropical rainforests. Rainforests have been chosen as the focus since the research paper mentions rainforests being high-priority conservation biomes. Nevertheless, the researchers mention that the following points can be applied to other biomes.
[19], [20]	More insight on wildlife monitoring methods. Monitoring wildlife with the help of acoustics.	'A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation' [19] provides much insight into wildlife monitoring and conservation and discusses different sensors and methods of application. The usage of each sensor type for this specific topic is mentioned and explained. More of this can be found in 'Acoustic monitoring in terrestrial environments using microphone arrays: applications, technological considerations, and prospectus' [20], in which the usage of microphones in an array is discussed. This way, the sounds of birds can be recorded in multiple places at the same time to better map the animals.

Chapter 2: Identification of General Problems and Challenges

<To be prepared the 1st to 2nd week>
Identify 8-10 general problems & challenges from the list of publications in Chapter 1

1. How can nocturnal animals or night-time be more efficiently monitored?
2. How can migration route change, due to human infrastructure, be avoided?
3. How can the unnatural behaviour of animals, due to human influence, be prevented?
4. How to predict/prevent animal behaviour changes due to climate change? (Extinction, early breeding, etc)
5. How to solve animal habitat loss due to human activity?
6. How can the cost of wildlife monitoring of large populations be reduced?
7. How to make animal monitoring more efficient?
8. How to handle the loss of biodiversity to protect animal populations?

Chapter 3: Identification of Relevant Problems

<To be prepared the 2nd to 3rd week>

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

1. **The effectiveness of ecoducts is not yet tested fully** – the extent to which ecoducts are used by animals in the area to cross over has not been tested. For this reason, it is not fully known if ecoducts as a project is worth building and spending money on. Furthermore, the extent to which it affects animals in the area has not been measured.
2. **Some countries have affected wildlife to such an extent that it is difficult to find fully natural wildlife** – countries like the Netherlands [22] have almost no wilderness, because of this there is no natural wildlife. It is important to monitor wildlife that is still left to prevent extinction.
3. **Information regarding wildlife monitoring can sometimes be not as widely accessible/widened** – techniques and monitoring projects on wildlife may not be ethically acceptable to everyone, as it is not always clear as to the extent of how much the animals and their biodiversity is affected. The number for research papers/articles related to the dangers and ethics of wildlife monitoring is drastically lower than other relevant topics. While wildlife monitoring can often be helpful in counting and helping animal populations, it is likely to have negative effects on their daily life and diversity that are not fully taken into consideration.
4. **Some species that tend to crossroads more frequently, like badgers and foxes [23], and therefore get hit by traffic more often. Moreover, they are both nocturnal and avoid human contact [2]** – there is a need to create a system that warns drivers that there is some animal activity near the road, therefore they should slow down and be more attentive. This theoretically should minimise the amount of roadkill that happens, even with the presence of an eco-duct. This system should be both effective at night and day.
5. **The population of wolves in the Netherlands and their effect on surrounding wildlife populations is not yet monitored effectively** – not all aspects of how the wolves have affected their surrounding populations and the ways their absence would mean different habits for other species have been monitored.

Chapter 4: Problem Selection and Motivation

<To be prepared the 2nd to 3rd week>

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

Due to the high number of mammals (29 million) being killed in road traffic accidents [24], out project group has collectively decided to tackle the following challenge: <u>detecting any animal activity near roads and based on the present activity, warn drivers using signs.</u>

This is done with the intent to minimise unnecessary roadkill incidents, even with the presence of animal road crossings. Even though animal crossings already allow animals to cross active roads effectively, the consistent usage of these crossings is not guaranteed. This issue becomes troublesome to fix, due to the inevitable disturbance of natural animal activity. Our group decided it would be a more logical decision to have a reliable method of warning drivers about nearby animal activity. This way we could encourage drivers to stay attentive and retain natural animal activity without disturbing them.

Chapter 5: Potential Solutions

<To be prepared the 3rd to 4th week>
Find 5-8 potential solutions to your problem. Explain how these solutions could work

Number	Solution	Elaboration
1.	Gather data at animal crossings with the use of a laser tripwire and PIR sensors.	This is a simple and cost-effective way to gather a lot of data about animals. A network can be created with these sensors. Various kinds of sensors could be added. With the gathered data animal crossings can be improved.
2.	Identify animals near animal crossings by using cameras and analysing their behaviour.	With the use of open-source software animals can be detected so the system can work autonomously. The cameras can be triggered so they only turn on when needed. With the data, animal crossings can be improved
3.	Decrease the disturbance of animal crossings and improve the usage of ecoducts by luring animals to the correct spot or make use of underground animal crossings to reduce the impact of traffic.	By blocking light and sound on the animal crossing that are above/on the road, animals would be less prone to disturbance, therefore retaining their natural activity. Additionally, this issue can be avoided altogether by using an underground animal crossing. Animals could be lured into either of these entrances by using blinking lights pointed towards fields, that are located near dangerous open road areas.
4.	Improve awareness of drivers in areas where animals pass regularly with the use of indicator/warning lights.	This way a driver knows that an animal is nearby and would be encouraged to reduce their driving speed. One thing to keep in mind, the speed of a vehicle needs to be considered. The lights should indicate any activity ahead of the light or in the vicinity of the light, and not next to it.
5.	Making a network of devices with sensors to monitor not just the animal crossing, but the surrounding environment as well, to create a broader image of animal behaviour near the crossings.	This would prove to be useful for the main goal of collecting data. It is more logical to monitor a large area, rather than monitor only an animal crossing. This would work very well in conjunction with solution number 4. Using a warning sign connected to a sensor system that detects any animal activity nearby the road would allow drivers to be

		warned, and therefore, lowering the possibility of a roadkill incident happening.

Chapter 6: Solution Selection

<To be prepared the 3rd to 4th week>

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

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

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

Final choice:

The selected solution is about warning drivers when an animal approaches the road. By making a smart environment of sensors that sense when an animal is near a road. When the sensors output that there is movement on the side of the road, the driver on the road is warned by making a light blink. The entire system will be connected to each other. An expansion for the system can be tracking the number of passing cars, so the data about the animal activity can be compared to the traffic density. The system will be completely autonomously working, so the drivers are warned, and the data is gathered without the need for human interaction after the setup is initialized.

The reason this solution is selected is that it has a very direct impact on road safety for both animals and humans. Making drivers aware of animals approaching the road decreases the chances of accidents happening.

Modular approach:

The selected solution contains multiple modules that will communicate with each other to make one smart environment.

Along the side of the road there will be modules with sensors, the sensing nodes. They can detect general animal activity. In the case of an animal activity event the node will send it to nearby nodes, and these will relay the event through the network.

As an optional addition we could add a measuring road activity. To evaluate the system there is the road sensor node, this will be able to detect road traffic speed and frequency of traffic and save the data, so the system can evaluate its own effectiveness by correlating car speed with animal activity.

Project specifications:

Specifications	Must	Should	Could	Do not
Drone usage				■
Tracking the number of cars passing on the road		■		
Camera to identify animal			■	
Detect animals	■			
Count animal activity		■		
Durable		■		
Work autonomously	■			
Be cost effective	■			

Visualise the gathered data				
Not disturb the ecosystem				
Compact system				
Scalable				
Aesthetically pleasing				
Ease of installation				
LDR sensor for sensing light				

The project is currently in its early stage. Due to this, it is difficult to specify tasks related to the prototyping. The following table depicts the roles of each project group member, later during the project, modules can be assigned to each individual team based on the roles that they have been assigned.

Chapter 7: Methodology

<To be prepared the 4th to 5th week>

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.*

Planning:

Week number	**What needs to be worked on?**	**When/what needs to be finished?**
Week 4 (Dec 5th – Dec 11th)	Chapter 7	–
Week 5 (Dec 12th – Dec 18th)	Chapter 7 Chapter 0 Order hardware parts	Chapter 7: • Address points/questions • Time plan • Ambitious vs. basic plan • Solution decomposition into modules/tasks • Task assignment to team members <u>CHAPTER 7 DEADLINE – 15TH OF DECEMBER</u>
Week 6 (Dec 19th – Dec 23rd)	Chapter 0	Chapter 0 (introduction)
Holidays	Start prototyping (if possible/feasible)	–
Week 7 (Jan 9th – Jan 15th)	• Improve prototype • Chapter 8 (validation of results) • Chapter 9 (adding results, findings, conclusions to our report)	–
Week 8 (Jan 16th – Jan 22nd)	Chapter 8 and chapter 9	3 min presentation of the first prototype
Week 9 (Jan 23rd – Jan 29th)	Prepare a demonstration for the demo-day	Chapter 8 and chapter 9

Microcontrollers that are connected in a chain wirelessly. One primary node needs to store the data. Each node has an indicator light, neighbouring lights will also turn on. Each node is detecting animals and notifies the chain when this happens.

Basic scenario:

The basic version of the prototype will be able to detect animals using a PIR sensor and give a signal to a microprocessor which then lights an LED to warn drivers. There will be intercommunication between the different nodes. The setup will be durable and non-disturbing to the ecosystem. It will be as cost-efficient as possible and scalable so it can cover various us distances.

Ambitious scenario:

The ambitious version of the project will have the nodes, with one node being a primary node that can store all the received and transmitted data. It will also have a laser tripwire to detect the speed and the number of cars. This way we can also correlate the number and speed of cars to the number of animals that are detected. And the effect of the lights on the drivers.

This solution has many features that make it qualify as a smart environment. To start with, the system can detect the presence of wildlife next to the road in an autonomous matter. The fact that the system is also capable of detecting the passing cars on the road and its capacity to know its location, both in general and in reference to its neighbouring nodes, make it more context aware. It's networked nature also makes it distributed. An extra way of making the system context aware is by adding a LDR sensor. This would be used for sensing whether it is day or night. This can be used for turning the system into sleep mode during the day for energy conservation.

The system will sense the presence of animal activity with a PIR sensor. All the information will be processed and passed between nodes using a microcontroller, which will also potentially store the information in an SD card. The system will light up a series of lights to warn the drivers on the node that detected the animal and its neighbouring nodes. One small detail that could be encountered is that the PIR sensor needs to be calibrated for sensitivity. So, the system needs to have a way to access the calibration in an easy and safe manner.

The system would not be used in a controlled environment. It is aimed at detecting animal activity near roads, where the conditions are unknown. The weather, temperature and many other variables are factors that may affect the effectiveness of this system and would therefore need to be addressed. The PIR sensors that are triggered because of nearby animal activity will turn on a light on the side of the road. Additionally, it will communicate to the node which will store the data on the number of animal triggers.

The lights are activated by a signal from the PIR sensors, so that the drivers are warned in real time about the potential dangers on the road. The system itself will be tested by looking at the number of true and false positives detected by the PIR sensors. Then to measure the effect of the system and its effectiveness for the public can be validated in the following ways. First, by measuring the amount of roadkill on certain roads before and after the system has been implemented. And secondly, by observing the effect on drivers. Which will be measured by surveying the public on their agreeability and perception of the product.

When it comes to data collection, the main thing we need to focus on is when the PIR sensors detect any animal activity. Additionally, if we implement the system to be able to track the number of cars passing by, then we would need timestamps for that. Instead of having a lot of timestamps that indicate when a car passes, we could potentially track cars for certain time periods, for example: "between 14:00 and 15:00 20 cars passed". The data is simple, so storing a large amount of data entries should not be a problem. The plan is to store all the data on an SD card.

The nodes would have to be encased in a waterproof case to prevent water damage from rain, dew etc. It additionally should be able to let radio waves pass through for communication between nodes.

The methodology of our idea will lead to a smart solution that will make drivers aware of animal activity near the road. By letting them know, they will have the time to slow down and be aware of the surroundings, therefore avoiding animal deaths on the road. In contrast to the already existing warning signs of areas with animals, this will indicate danger in a smart and real time manner, to give a more meaningful warning.

Hardware requirements:

Material	Specification

Basic	
Batteries x3	9V should be enough.
LED lights	10 per box or led strips.
Enclosure	3D printed or laser cut.
Reflective Light holder	Acrylic with reflective layer.
PIR sensor	Needs to be sensitive enough. And have a range of a few meters.
Ambitious	
SD card holder	Needs to communicate with microcontroller.
SD card x1	With enough storage 16GB or even less should be enough.
IR lasers trip wire	Needs to work over a large enough distance. Used to detect number of cars and their speed. Could also be used to detect animals.
Micro Controller x3	With Wi-Fi and or Bluetooth capability.

Software requirements:

Requirement	Elaboration
Basic	
Communication between nodes	The different nodes should be able to communicate by handling networks, IDs of nodes and communicating with neighbours.
Data processing for model	Output collected data into visual.
Sensor input processing	The microcontroller should react to sensor input by sending a signal to other nodes.
Node reaction to network input	The nodes should be able to receive and react to incoming data from other nodes.
Ambitious	
Data specification	Specify the collected data entries by mentioning the time of activation and the executed action.
Transferring data to SD card from microcontroller	The microcontroller should be able to store the retrieved data onto an SD card.

Solution decomposition:

Basic:

- Microcontroller modules/sensor/shield selection and purchase.
- Design and testing of circuits.
- Microcontroller programming of networking.
- Microcontroller programming of sensor input processing.
- Research, design, and testing of enclosure for modules in real and lab environment.
- Research, and design of effective warning system that does not distract drivers.
- Building of warning system.

Ambitious:

- Microcontroller programming of data collection and analyses.
- Research and development of car detection system.

Divided tasks/roles:

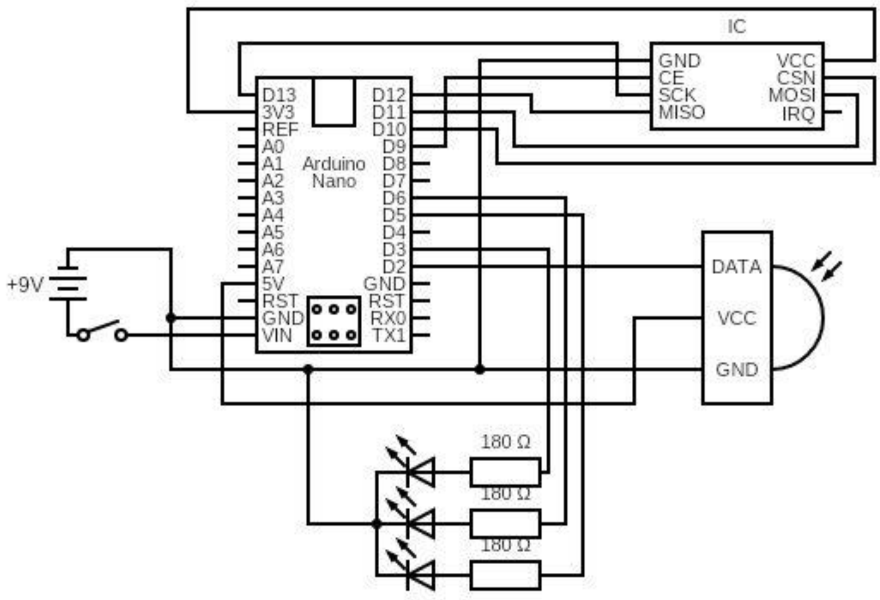
Teams	Roles	Modules
Denas	Documentation	Improving/Managing the project report
Torben	Team management	Managing the teams + helping electronics
Folkert and Willem	Software	RF signals, PIR signals
Anna and Tomas	Design	3D printed casing, Demo and Presentation
Julian	Hardware	Electronic Circuit (battery, Arduino, antenna, PIR sensor, LED), Demo electronics

Chapter 8: Validation

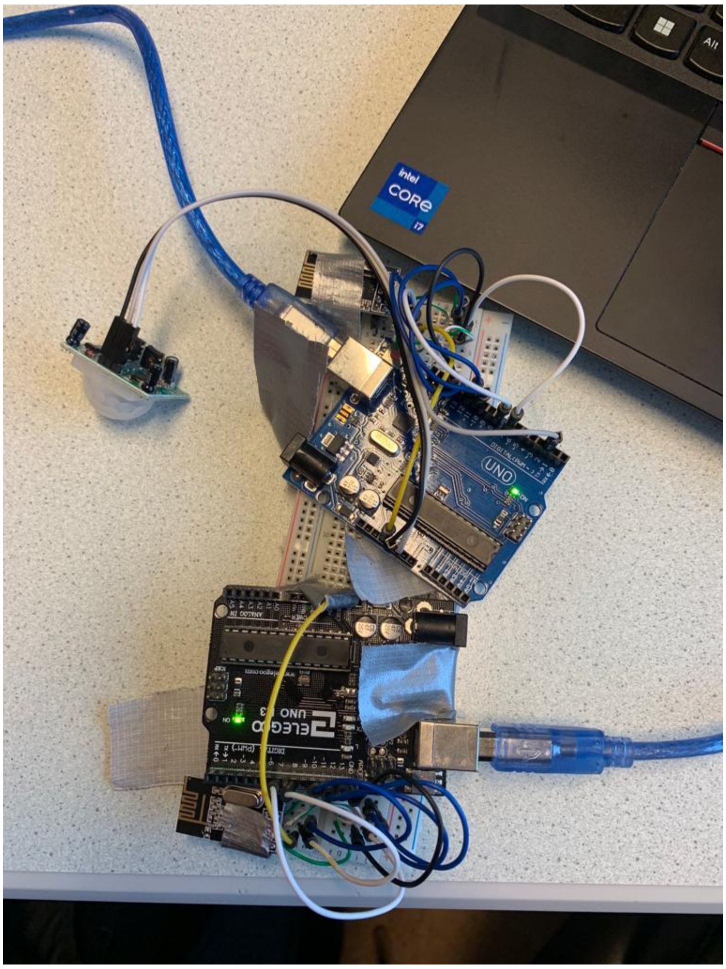
<To be prepared the 8th to 9th week>
Validate your results through some tests and/or some scientific evaluation process

Finalised prototype:

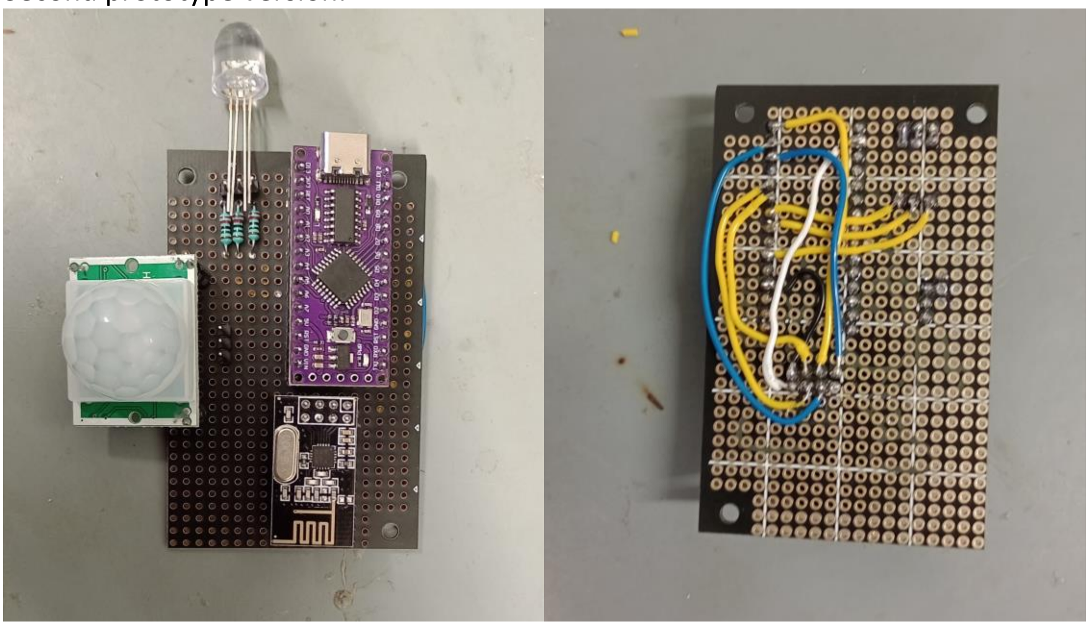
Circuitry:



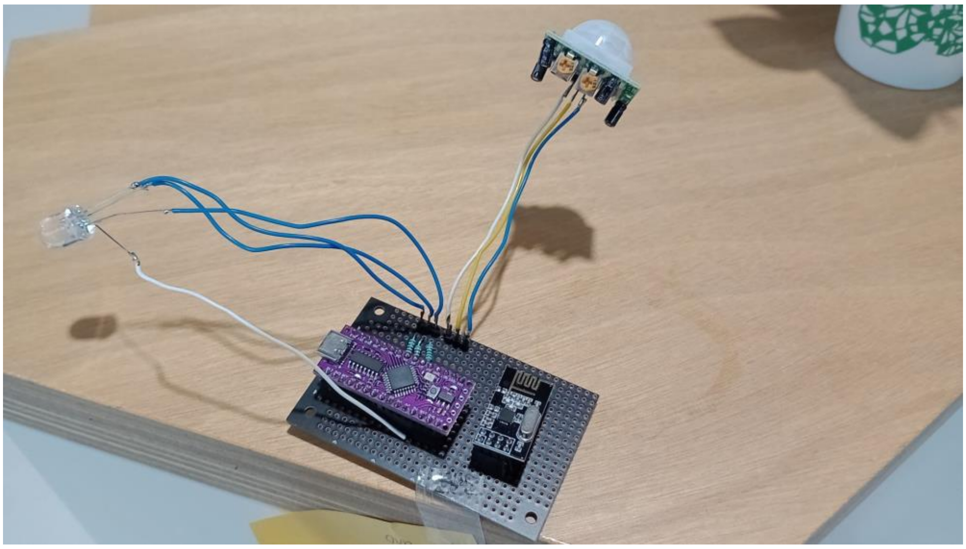
First prototype version:



Second prototype version:



Final version of circuitry:



Testing methods:

1. Test one person passing the sensor **(Bare Minimum)**
2. (If above holds) Test multiple people passing by **(More Realistic Scenario)**
3. Do a small-scale test on bike lanes **(Simulating Final Environment)**
4. Small, warm entities passing the sensor **(Accuracy and Range)**

The testing methods are written based on their significance. The bare minimum that our system should be able to complete is the very first test. The passing of one test

The most crucial factor that we must consider during all the tests is the number of accurate system observations. This factor is the best method of validating how reliable our prototype is.

Elaboration:

1. Once our prototype is ready for testing, the first test that should be carried out should be seeing if our prototype is even capable of sensing a warm body and acting accordingly. Passing this test would mean that our prototype has reached our desired expectations. The following tests deal with calibrating/evaluating the system in more complex scenarios.
2. In the real-world it is not always the case that one entity passes by the sensor at a time. It is possible for multiple entities to pass through simultaneously. It is necessary to ensure that our prototype can handle such situations. Ideally, the warning light of our prototype should be on continuously if there is activity near the sensors.
3. An environment most similar to a road/highway location would be a bike lane. This is the final test that would show how plausible it would be to have our prototype working in a road/highway environment. This test is similar to our second test method, with the main differences being the speed of the subjects and the inconsistent patterns of travel.
4. Finally, after the three tests have been carried out, it would be interesting to know how accurate our system is. Testing the range of our PIR sensor is straightforward, we will just adjust the distance between the PIR sensor and the subject being sensed and observe what is the maximum distance that the system can work with accurately and

consistently. Secondly, knowing how small an observed entity can get is especially useful information. The findings of this sub-test will prove that smaller animals can also be detected by our system, making the system more inclusive.

Additional Information:

It was decided that testing battery life would be irrelevant. This is due to the reason that, if we were to (theoretically) scale up our system of nodes to a road/highway scale, powering our system with an array of batteries would be inefficient. It would make more sense to power the system with the existing power infrastructure near the road. It would provide easier control of powering the system and troubleshooting in case there are any observed irregularities.

During the holidays, our project group leader – Torben, met up with a forest ranger that oversees the flora and fauna of the Ullenberg estate (near Ermelo, Veluwe). When he was giving a tour of the wilderness reserve the conversation led to animals and the interaction between humans. Torben asked him about animals and the effects the roads have on them. The forest ranger told him that a week prior a woman was driving her car along a road and a red dear jumped out of nowhere in front of her car. The dear crashed through her windshield, almost hitting the woman with its antlers. Luckily, the woman only suffered minor cuts from glass shards and a hefty shock. He told Torben that animals getting hit by cars like that happen more often around the area. The forest ranger also told him that there was no satisfactory solution for the problem, except lowering the speed limit to give people more time to react. Unfortunately, lowering the speed will not help with solving the problem, since backroads are notorious for people speeding, according to the forest ranger. When Torben proposed our solution to lowering animal road crossing accidents the forest ranger was excited. He believed that giving people more time to react will solve a large part of the problem. Also, most crashes occurred during sun rise or sun set when animals are most active and visibility can be low, according to the forest ranger. Showing a light when animal activity is sensed near the road will get the drivers to pay more attention and increase their reaction time. To conclude the story, according to an expert, due to the underwhelming effect of traditional warning methods related to animal activity, our proposed solution has the potential to become a more effective and reliable way of warning drivers about near-by animal activity.

Time	Test	Location
13:45-14:00 (15min)	1 person walking by	Inside
14:05-14:35 (30min)	Multiple people walking by	Public location (Hal B or Horst)
14:40-15:20 (40min)	Bike lane test	Bike lane
15:25-16:35 (10min)	Accuracy test	Inside/Outside

Chapter 9: Results and Conclusion

<To be prepared the 8th to 9th week>
Add to your document your results, findings, conclusions

Table of test observations:

Test	Status (PASS/FAIL)	Observations	Changes made
1 person walking by	**PASS**	Out of 10 measurements we had 10 triggers. All the lights turned on, as expected. In the serial monitor it is visible which of the nodes turn on. There were no false positives, and every passer-by was detected for a range of 5m.	–
Multiple people walking by	**PASS**	Out of 30 measurements we had 30 triggers. Same for single person. The PIR is not able to distinguish whether there is one person or multiple people passing by, but it is activated every time.	–
Bike lane test	**FAIL**	Out of 10 measurements we had 8 triggers. However, the radio signals were limited to a range of 10 metres. PIR sensor reacts most of the time but has trouble detecting someone behind bushes.	Increased range of the Radio to 60-70m
Accuracy test	**–**	We observed that one of our nodes was able to detect a cup of hot water from about a meter away. This proves that our system would be able to detect even small 5-10 cm in size animals.	–

Discussion of the results:

With the tests that were performed we can conclude that the system can detect people at a significant range.

During our first two tests we encountered no significant issues, the system worked as expected. In the third test the limited range of the nodes was a problem, but we managed to massively increase the range due to an alteration in the code.

The only main concerns are the range of the PIR sensors. For an actual implementation, a detection range of 10m-50m would be better. To achieve this range other sensors might have to be used.

During the tests outside it became apparent that LEDs are a very weak way of warning near-by people about any detected activity in our testing conditions. In the final product, the light will be reflected by aluminium foil, and the reflected light will be evenly spread out by a frosted acrylic plate. Lastly, the test was carried out during the day, and the final product will mostly be used at night, since that is when drivers are less aware of what is happening on the side of the road. An additional warning sign at the beginning of the testing range mentioning the function of the lights would be optimal to make drivers aware of the meaning of the lights. For demonstration purposes our current version of the system would be more than sufficient.

Conclusion:

Our group concluded that the hardware that we are using is the bare minimum requirements for a system that we envisioned. For example, when sensing a cup of hot water, the range of our PIR sensors is limited to 1 meter. To make the system more accurate, increase the range and so forth, it is necessary to upgrade the electronic components for our system. Due to financial constraints, this is not feasible.

Other than that, we have successfully implemented a basis for a warning system that notifies near-by people about any activity that is detected by the PIR sensors. The hardware of the system can be easily customised based on the needs of the user. The original purpose of such a system is to warn near-by drivers about animal activity, therefore lowering the potential number of roadkill incidents.

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