UNIVERSITY OF TWENTE.

Smart Environments Project

Documentation Report

Team 15: The Naturegazers

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Table of contents

Introduction

This report was written by Team 15, the Naturegazers. The team consists of Chris Blaauwgeers, Alexander Derevyagin, Fleur Derks, Juul Jelles, Merel Kok, Thijs Koster, Emilia Pavel, and Daniel Pheiffer. The problem at hand is the following: *"Suburban Wildlife tunnels aren't yet optimized, by monitoring them extensively it will give the designers a better idea of how to improve the tunnels to prevent even more roadkill during migrations".* The reason for choosing this is that due to urbanization, nature gets pushed back more and more. Wildlife areas are being fractured leaving animals no choice but to cross busy roads risking their lives.

To help animals, wildlife tunnels underneath roads are being implemented. However, these roads don't always work. Some animals may not use them which still leads to segregation. The proposed solution is to use a combination of sensors to determine the type of animal entering, and if not possible, take a picture of them to identify them. When done correctly, the information can be compared to the data about the species that live in the area and the tunnels can be improved to comply more to the animals not yet using the tunnels.

Chapter 1: Relevant Citations

1) Dutch forest monitoring network, design, and results

In this research, a group of scientists provided statistical information regarding the total forest area, the commonest trees and flora species, the average lifetime of the forests etc. For estimating, a miscellaneous number of techniques was implemented: stratified random and sampling, less popular unaligned systematic sampling etc. As a result, the table of vital forest resources appeared, what helps to create the exact image of what Dutch forests are today. [1]

2) Methods for wildlife monitoring in tropical forests

An investigation was conducted dedicated to tropical flora and fauna observation. In their work, they compared and provided advantages and drawbacks of three mentioned methods of wildlife monitoring: visual or acoustic devices, camera traps and passive acoustic sensors. The evaluation was based on four questions, regarding the target species, preferred population metrics, required tools and effort for species identification and needed financial and human resources.[2]

3) Wadden Sea Quality Status Report - Migratory birds

Kleefstra et al. (2022) released research regarding bird migration on the territory of such regions as Wadden Sea, Canada, Russia, Western Europe, Africa. In this work, they operate with data which was collected over the past three decades regarding thirty-four species. During their work, Kleefstra et al. (2022) faced a few limitations like air traffic, inconvenient climate conditions and drawbacks of modern monitoring systems. Eventually, they indicated growth in population of 7 bird species, 14 remained the same and 13 showed the decreasing tendency. Nevertheless, for the past ten years the larger number of migratory birds has been increasing. [3]

4) Ranger perceptions of, and engagement with, monitoring of elephant poaching

Elephant poaching, that is based around the effectiveness of patrol groups. Much quantitative research has demonstrated the downfalls and data collection potential of rangers, but little work has been done to consider human dimensions. However, the few examples of these cases have resulted in poor management and execution of these programs, possibly compromising data quality. [4]

5) Boots on the ground: the role of passive acoustic monitoring in evaluating anti-poaching patrols

Anti-poaching units making use of data generated by acoustic measuring devices. The idea has been gaining popularity as a means of monitoring autonomously, with the possibility to replace previous methods such as patrols, however, there have been no documented successful executions of a system. [5]

6) Anti-Poaching Drone Control

System of drones used to fly over predetermined routes / areas to monitor for suspicious poaching activity based on machine learning. The main goal is to help conserve marine life while decreasing resources needed. [6]

7) Integrating Remote Sensing into Wildlife Monitoring for Conservation

A large-scale field survey was performed after remote sensing data didn't record any chimpanzees in an area notorious for having them. This survey resulted in an accurate count of chimpanzees and proved the necessity of doing in field research as supposed to only using remote sensing data for some types of wildlife. [7]

8) Insect declines in the Anthropocene

Decline of insects worldwide due to habitat destruction and agricultural intensification. Other factors such as atmospheric nitrification and effects of droughts. Needs monitoring efforts, especially across ecological gradients to identify important causal factors in declines. [8]

9) Standardized Assessment of Biodiversity Trends in Tropical Forest Protected Areas: The End Is Not in Sight

To better improve wildlife monitoring in tropic forests, a new, standardized camera trapping tool was used to better compare data between different areas. This tool was used in multiple areas worldwide. [9]

10) Plastics, the environment, and human health: Current consensus and future trends

Impact of plastics on wildlife. Especially marine wildlife. There are physical problems such as entanglement in plastic and harmful chemicals. This needs to be monitored more closely to make sure this happens less. The quantity of plastic use must come down. [10]

11) Ecological meltdown in predator-free forest fragments

Usually, two systems to describe ecosystem regulation are in place. The first of which being "top-down", this means that the presence of predators regulate the number of herbivores to prevent them from overexploiting a certain area. The other system is called "bottom-up", this means that plants protect themselves from herbivores using chemical defenses. A test on a small island in Venezuela was performed, this island was predator free. After a while, all plants on the island were severely reduces proving the "top-down" model. [11]

12) Sensing Solutions for Collecting Spatio-Temporal Data for Wildlife Monitoring Applications: A Review

The article talks about different ways to collect wildlife monitoring data, for example solar, radar or lidar. It also talks about the doppler effect which is about the change in the frequency of a wave in relation to an observer who is moving relative to the source of the wave. It also talks about thermal sensors, cameras, chemical sensors and others ways to detect wildlife. [12]

13) Precision wildlife monitoring using unmanned aerial vehicles

Unmanned aerial vehicles (UAVs) represent a new frontier in environmental research. Their use has the potential to revolutionize the field if they prove capable of improving data quality or the ease with which data are collected beyond traditional methods. They made pictures above ground of the species and then counted them with adobe photoshop. [13]

14) Internet of Things for wildlife monitoring

An introduction on the research on IOT for wildlife monitoring and focus on three important and fundamental application topics for relative ecology and zoology research: location tracking, habitat environment observation, and behavior recognition. It also introduces four research aspects for system implementation: identification, mobile access point, monitoring device, and application. [14]

15) Monitoring Small Animal Usage Patterns of Suburban Wildlife Tunnels: Behaviour, Design, And Recommendations

A paper about Underpass crossing structures that reduce the effect of road mortality by facilitating safe passage during migration, dispersal and movement. The article puts an emphasis on the importance of monitoring and why it is important withing the given context. It explains how monitoring was done and what their recommendations would be for future researchers / designers. [15]

16) Developing camera-trapping protocols for wildlife monitoring in Chinese forests

This paper takes a closer look at the plan of monitoring forest dynamics in China using camera-trapping. This way it is possible for studies to take a closer look at wildlife diversity and use this data for further research. This paper also emphasizes on the significance of camera-trapping as base of wildlife monitoring in forest ecosystems. [16]

17) Magnetic resonance imaging for non-invasive measurement of plastic ingestion in marine wildlife

Measuring the ingestion of plastic waste in marine wildlife is important for both the level of pollution in the ocean and to understand the short- and long-term effects it has within the environment. This study investigated using a less harmful method of monitoring this problem, however, not only are MRI's extremely expensive and not suitable for field use. [17]

18) A review of wolf management in Poland and Germany with recommendations for future transboundary collaboration

Ever since the Wolf has entered the Netherlands in 2019 there have been many problems, especially concerning lifestock killings. Therefore it is interesting to look at this article and see how Poland and Germany manage the wolf with the usage of monitoring. This article is about the ways of dealing with the wolf for countries that haven’t dealt with it before. Since the wolf is a protected species killing them is not an option and countries need to find different ways of dealing with it. The article talks about how development of common monitoring standards and monitoring in general can be of great value when it comes to dealing with the wolf. Lifestock needs to be protected and the population size of the wolf needs to be monitored. [18]

19) Drones count wildlife more accurately and precisely than humans

It is difficult to count the wildlife population. There is the traditionally ground-based counting method, but ecologists try to use different technologies to make it easier to count different species. They had the goal to count the number of fake birds. The drones did a better job with counting the fake birds than the ground-based data collection methods. The new method has more accurate and precise data to use, and it is easier to use for fine scale population. This gives more information for ecological management. [19]

20) Monitoring International Wildlife Trade with Coded Species Data

International trade should be a regulated procedure with trading partners ensuring the goods are up to a certain level of quality, however, there is no standardized, retrievable form from which to capture the species-specific data. This article investigated creating an international coding system / database for all countries to make use of. [20]

Chapter 2: Identifying problems

1) On the “Wadden-islands” stray cats form a big problem killing thousands of animals each year tracking the population allows us to handle accordingly
2) Livestock needs to be protected in the areas where the wolf is becoming more active, therefore monitoring of the wolf population is crucial.
3) Suburban Wildlife tunnels aren’t yet optimized, by monitoring them extensively it will give the designers a better idea of how to improve the tunnels to prevent even more roadkill during migrations. And maybe ways to implement these tunnels for other animals.
4) Plastic has negative impacts on wildlife and therefore it forms a big problem to nature and to human health.
5) There are groups of people who actively go against the preservation of wildlife that need to be identified / stopped therefore tracking animals that are at risk is crucial to prevent poaching
6) Non-migratory birds seem to have a hard time finding food in winter. Tracking may give useful data on the location of food sources.
7) The geographic extent and magnitude of insect declines are largely unknown, to know more about this monitoring insects that are at risk of extinction is important.
8) Natural events like earthquakes, forest fires, hurricanes etc. Can be very deadly, by monitoring nature and looking at the things that signal that there is a natural disaster coming allows us to act accordingly faster and can save a lot of lives

Chapter 3: identifying new problems

Previous problems

The problems that were determined in chapter 2 are as follows.

1) On the “Wadden-islands” stray cats form a big problem killing thousands of animals each year tracking the population allows us to handle accordingly
2) Livestock needs to be protected in the areas where the wolf is becoming more active, therefore monitoring of the wolf population is crucial.
3) Suburban Wildlife tunnels aren’t yet optimized, by monitoring them extensively it will give the designers a better idea of how to improve the tunnels to prevent even more roadkill during migrations. And maybe ways to implement these tunnels for other animals.
4) Plastic has negative impacts on wildlife and therefore it forms a big problem to nature and to human health.
5) There are groups of people who actively go against the preservation of wildlife that need to be identified / stopped therefore tracking animals that are at risk is crucial to prevent poaching
6) Non-migratory birds seem to have a hard time finding food in winter. Tracking may give useful data on the location of food sources.
7) The geographic extent and magnitude of insect declines are largely unknown, to know more about this monitoring insects that are at risk of extinction is important.
8) Natural events like earthquakes, forest fires, hurricanes etc. Can be very deadly, by monitoring nature and looking at the things that signal that there is a natural disaster coming allows us to act accordingly faster and can save a lot of lives

New problems:

The list of problems that will be chosen from is:

1) Livestock needs to be protected in the areas where the wolf is becoming more active, therefore monitoring of the population is crucial.
2) Suburban Wildlife / Climate tunnels aren’t yet optimized, by monitoring them extensively it will give the designers a better idea of how to improve the tunnels to prevent even more roadkill during migrations, because certain animals have preferences when it comes to travelling, these preferences can be used when designing the tunnel. This way certain tunnels for certain species can also be combined.
3) Non-migratory birds seem to have a hard time finding food in winter. Tracking may give useful data on the location of food sources.
4) There is not a lot of information regarding how different species living in the same natural conditions interact with each other. like how the Japanese great tit (Parus minor) birds communicate. Making dummies of a Parus minor bird will help to get information on their interaction habits.
5) On the “Wadden-islands” stray cats form a big problem killing thousands of animals each year.

Chapter 4: Choosing a problem

The problem that was decided to work on is *"Suburban Wildlife tunnels aren't yet optimized, by monitoring them extensively it will give the designers a better idea of how to improve the tunnels to prevent even more roadkill during migrations. Also gathered data will provide clarity on how to implement these tunnels for other animals.".* This is because of the following:

Due to the population growth of last and coming years, an increase in for example roads, will lead to a decrease of their living space and splitting of habitats of small wildlife. This fracturing of natural areas is expected to continue in the upcoming period. To counteract this movement, wildlife tunnels are implemented under roads to join habitats together. These tunnels, however, are not optimized for the current and future situation and leave space for improvement. With the help of the information that will be received through these smart technology tunnels, using lasers to detect the species of animals, and if these lasers are not certain pictures to define the species, more accurate tunnels can be built to satisfy the needs of wildlife animals. Together with the known information about the species that live in the same area the tunnel can be optimized. The prototype will be used to test the accuracy of the lasers and the program connected to them, by using a variety of small sized fake animals.

Chapter 5: Potential solutions

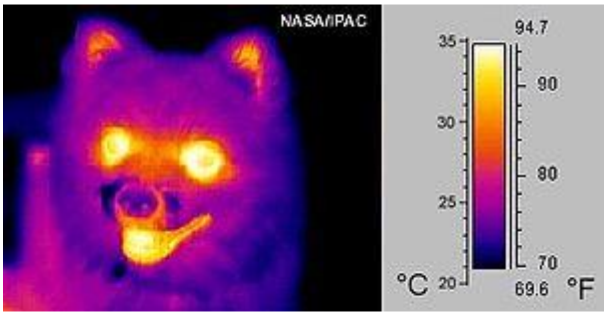
The solution for the problem may consist of multiple parts. Some of these solutions are:
The first one is using motion sensors in the tunnels to determine if an animal is present. The cameras will detect when an animal is in the tunnel and will be inside the tunnel. This is a good way to see if the tunnel gets used and collect data on the amount of animals that go true the tunnel. The downside is that you cannot see what kind of animals go through the tunnel or if two animals go in the tunnel at the same time, it is not clear if the animal will go through the tunnel or just go back.

The second solution is using a camera, that turns on with motion sensor, that captures a photo/video of the animal. This can show what kind of animals go true the tunnel and based on that information you can make future improvements, so more animals will use the tunnel. The downside is that taking pictures of the animals uses a lot of unnecessary storage and still needs a person to check all the photos.

The third solution is using lasers to determine the size of the animals. The laser will have different heights, so it will determine the size of the animal. It will use less data and will determine if the tunnel needs future improvement and what size of animal uses the tunnel the most. The downside is that it is hard to determine what size some animals are because younger animals are smaller than older ones and it is hard to put exact height measurements with the lasers. You don’t really get a specified answer on what animals use the tunnel.

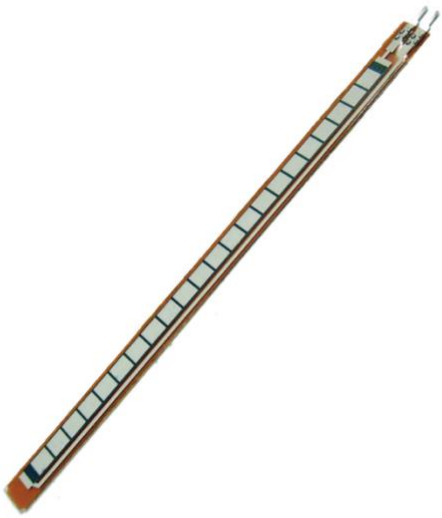
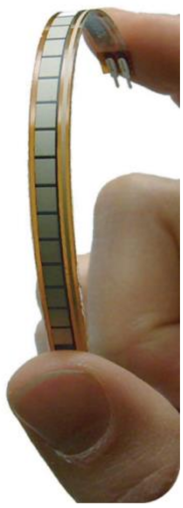
The fourth solution is using pressure plates to determine the weight of the animal. The plates will be at the beginning and the end of the tunnel to see what animals use the tunnel and if the tunnel gets used. By subdividing the animals by weight, you get a clear overview and use the given data easier. The downside is that weight divers per animal and therefore is not a precise measurement and if multiple animals stand on the plate at the same time, the data is not valid anymore.

The fifth solution is using an infrared-heat sensor to determine the type of animal. These will be installed inside the tunnel and will sensor the animals because they have a different body temperature than their surroundings. Most animals have a constant body temperature, so it is easier to determine what animal uses the tunnel and it is also possible to see the height of the animal, so you have two characteristics that are usable for a dataset. Downside is that the camara stays on all the time and therefore needs a constant source of energy.



The sixth solution is putting sensors outside of the tunnel to check whether animals are willing to enter the tunnel. This will show if the tunnel needs future improvements, so animals are more willing to use the tunnel. By putting the sensors on the outside, you will get a better inside if animals use the tunnel or if they just go around, it or if they will wait in front of it. The downside is that if an animal goes true the tunnel it is hard to determine if the animal wants to enter the tunnel or if it leaves the tunnel. It also does not give an inside on what is going on in the tunnel.

Our last solution was using a flex-sensor at the entrance and exit of the tunnel to detect if an animal enters the tunnel. This will measure how much the sensor gets bend with that information it will determine if the tunnel gets used. The sensor only shows if it gets bend, so it can also be possible that the sensor gets bend by dirt and wood for example. This will make the data invalid.

Chapter 6: Choosing a solution

From chapter, several solutions will be combined into a workable plan. The whole plan comes down to:

1. A laser sensor will detect if an animal enters the tunnel.
2. Lasers built into the wall will determine the size of the animal.
3. If the size of the animal is in a “gray area”, the camera will turn on and a picture will be taken. From this image, a human can determine what animal is in the tunnel.
4. When the size of the animal is specific for a certain species, the camera will not turn on and the system will note the type of animal.
5. An extra sensor is used to determine the speed of animals going through.

An ambitious plan can also be made:

1. A real time clock will be added to give more information about the pictures.
2. Another sensor will be added at to the exit to determine the time and success rate of animals going through the tunnel.
3. Pressure sensors can be added in the floor to determine the weight of the animals going through the tunnel.

Chapter 7: Methodology

Product as a smart environment

The system is comprised of sensors that function independently from each other yet contribute to the overall environment. It is a device implemented in another habitat, linking a computer to an environmental setting. This defines the product as a smart environment.

This product will solve our initial problem as it will be collecting data such as pictures and size of animal and store it in a medium, which creates more information and data regarding the climate tunnels

Equipment

The equipment that is used to make the standard scenario consist of the following:

- 5x laser sensors
- Camera
- Tunnel
- 1x small, 2x medium and 1x large demo animals.
- SD card shield

For the ambitious scenario, some additional tools are required:

- Pressure sensors
- Flex sensors
- Foam for landscaping
- Real time clock sensor

Of these sensors, the laser, RTC and camera would need calibration. The laser would have to be programmed and calibrated as a “height scale”. There will be 5 lasers; 1 as a trigger for the system, and 4 used for the height detection: if the bottom laser is triggered, it will be categorized as a “small” animal, if the bottom two lasers are triggered, they will be categorized as “fairly small” etc. Hence the lasers would need to be programmed and calibrated for height measurement. The RTC will need to be calibrated to take date and time of the data collected to add a level of sorting and filing. The camera will need to be programmed to take a picture whenever there is an “uncategorized” animal, this would happen by the animal not fitting into any of the previous categories. If time runs out, an SD card reader will be used in replace of the database.

The tunnel will need to be built; the plan is to create a simplistic tunnel that will showcase the solution to the initial problem using wood (most likely plywood) and or 3D printing. The demo animals will be fake, preferably a toy animal that represents the actual animal (e.g., toy mouse) which could be bought from an online platform or sourced through friends and colleagues, that is if time allows, otherwise a model of an animal will be used.

Data

The information from the sensors will be processed by an Arduino board. The pictures, information about the pictures and information from the sensors will be uploaded to a database [21]. A computer will be used as a middleman for this. The Arduino will run completely once triggered by the first laser breaking, otherwise it will run in a low power mode to save battery. In terms of other data types, such as presence and height will be used to trigger the system and categorize the animal respectfully

Analysis

Once collected and stored, the goal of our product will be fulfilled as it would have provided data about the climate tunnels regarding what type of animals enter through height and possible weight detection. If time allows for a database to be created for this project, it will store all the information (date/time, picture and categorization) of the animals in a basic table layout.

Results

To validate the system, the prototype shall be tested with dummy animals. The information of the sensors can be checked to reality and in certain cases, the picture can then be compared to the information of the sensors. The information that is collected can tell you the species of animals going through the tunnel. This information can be compared to the known data about species in that live in the area. If a certain animal that does live in the area, doesn't show up in the data, the producer knows to optimize the tunnel for that species of animal.

Planning

Task	Moment	Team member
	Basic scenario	
Design and build the tunnel	Wednesday 25th of January	Thijs, Merel, Juul
Programming the Arduino and sensors	Wednesday 25th of January	Fleur, Daniel, Alexander
Set up the hardware.	Wednesday 25th of January	Fleur, Thijs, Chris, Juul, Merel
Documentation	Wednesday 25th of January	Chris
	Ambitious scenario	
Implementing pressure sensors		
Implement exit sensor		
Implement the RTC		

On a per week basis, the team will all work on their sections respectfully, and will be roughly broken down as follows: Week 7 (start of project) everyone will begin their tasks, with the tunnel being designed with measurements and material experimentation. The database will need to be planned out and experimented with. Hardware (Arduino plus sensors) will begin with testing out the sensors to ensure they work well. Week 8 will see a continuation of the work; the tunnel should be around 70% completed in terms of construction to ensure there is enough time for nice presentation. Hardware will need to have all sensors working individually and begin fitting the sensors together with the logic of how each would work together. Database should be seeing good progress otherwise a decision would need to be made to change over to an SD card shield. The final week, the tunnel should be finished and nicely decorated to ensure testing for the system is carried out smoothly. Documentation will be taken throughout the weeks.

Chapter 8: Validation

The testing goes as follows; we insert the animals in the system in a planned order to see if the system works. First, the main sensor should send a signal than an animal is entering the tunnel. When this is the case, the size sensors should turn on. Once the animal goes through these size sensor, one of three things should happen.

Small animal: only the bottom sensor should trigger:
  A signal is sent that a small animal has entered the tunnel at that moment in time.

Large animal: all three sensors are triggered:
  A signal is sent that a large animal has entered the tunnel at that moment in time.

Medium animal: the bottom and middle sensor are triggered:
  A signal is sent that a medium sized animal has entered the tunnel at that moment in time.
  A signal is sent to the camera that it should take a picture.
  The camera should take a picture and send it to the sd-card.

To check if the previous animals don't affect the next outcome, we do everyone one time in a random order.

Test phase:

Animal sent through	Main sensors	Size sensors	Camera signal	Speed (km/h)
Small animal	Yes	Small animal	None	0.42
Large animal	Yes	Big animal	None	0.46
Medium animal-1	Yes	Middle animal	Yes	0.62
Small animal	Yes	Small animal	None	0.58
Medium animal-2	Yes	Middle animal	Yes	0.58
Large animal	Yes	Middle animal	Yes	0.71

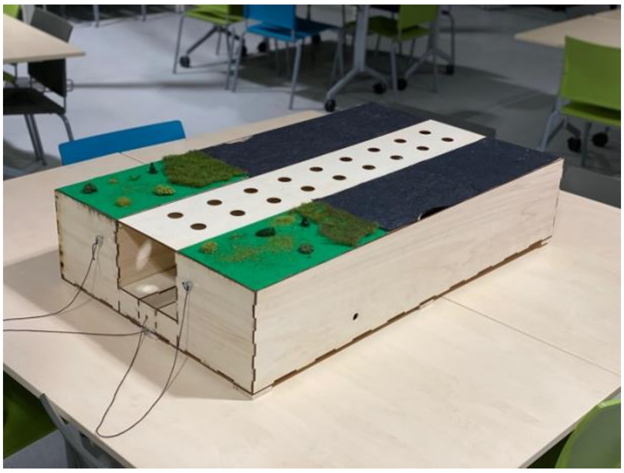


Figure 2: Full view of prototype

Figure 1: Inside view of the tunnel

Chapter 9: Results and conclusions

In the results, one can see that the system doesn’t work 100 percent right. This will be discussed in the next chapter. Apart from these mistakes, the system does what it is supposed to do. It can be concluded that this system can be used to determine animals in a wildlife tunnel.

Chapter 10: Discussion

Due to an unexpected failure of the material, the complete system did not work consistent when the sensor part and camera part were connected together. The sensor part of the system, so the part with the sensor at the entrance, the sensor to determine the size, and the sensor to determine the speed of the animal, did work. Sending through an animal gave the right determination and it also send a signal when the camera should be triggered. Besides that, the camera did work with an external button. Unfortunately, connecting these two systems together gave some problems. At certain moments the system seemed to work consistently, but after it was left alone for some time and then tested again, the camera did not take a picture no matter what. This went back and forth for some time. Our suspicion is that this problem is caused by some sort of tangle in the power-source and grounding that arises when connecting two system together.

To bypass this problem, while still being able to test everything, a decision was made to use a "human powered optocoupler". This means that the sensor part of the system was instead connected to an LED. This LED would always be turned on, and when it turns of, someone presses the button to trigger the camera. The decision to make it so as where the button is always on instead of off, was made because this simulates the hardware of the camera the best. The camera needed a constant signal, that when turned off, made the camera take a picture. Making an actual optocoupler would have been too time-consuming for in this project.

This system is obviously not ideal. In our opinion, however, this was the best way to be able to use the prototype and its function.

Another problem is the way the dummy animals were made. Both the large and medium dummy animals had the problem that their shape triggered the size sensor in a crooked way. Some part of the animal went in front of the sensors first, triggering it the wrong way, before all the right sensors were triggered. This resulted in the large animal sometimes showing giving a signal of a medium animal, and a medium animal giving a signal of a small animal or an unexpected signal. This problem should be able to fix. A solution for the prototype would be to change the shape of the animals or change the code. A change in code would be to make a delay before the size-sensors are read. This would, however, subsequently lead to the fact that animals can't go too fast or else the sensors might it. In the current setup this wouldn't help, since the entrance- and size-sensors are too close together so a delay would make you miss the animal all the time.

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Appendix

Appendix A: Program