BeetleBots

Designing and creating an exhibit with robots to spark childrens interest in robotics and provoke participation in ethical debates

Ishdeep Pal Singh Bhandari (6060927)
Ward Bannink (5882893)

Supervised By:

Wolfgang Huerst (UU) and Johan Otten (HKU)

03/07/2018

Abstract

As a joint operation between the HKU University of Arts and Universiteit Utrecht an exhibit on robotics was created in assignment of SETUP Medialab. The goal of the exhibit was to provide VMBO scholars a playful introduction to robotics and the concept of anthropomorphism. To accomplish this, the exhibit contains three teams composed of multiple beetle-like robots that try to push away snow from their base to make it another teams problem. As time goes by, the robots start to become more agitated with their work becoming undone and start to show aggressive behaviours towards other robots. The children can then help the robots to return to their normal state through exploration of numerous approaches. The interaction with the robot happened through transitioning between various behavioural states that elicited specific behaviours appropriate to their internal state and situation. This project was made possible due to the physical development skills of the HKU students, and the combination of artificial intelligence, object recognition, and colour detection provided by the UU students.

Acknowledgements

We thank the HKU and UU for the opportunity to work on this project along with three talented designers namely; Kris van Geel, Sascha de Waal and Collin Kasbergen. We also thank Wolfgang Huerst and Johan Otten for their profound guidance throughout the project.

Contents

List of Figures

Chapter 1

Introduction

These days, children doing vmbo for their secondary school education are looked down on, and not given as much attention as those who go to have or vwo. This has induced a lesser amount of confidence in these kids. In order to help kids improve on this and to prepare them for the future, in which robots are very likely to play a role connected to their lives, SETUP Medialab has initiated project Culture and Identity, that wishes to introduce VMBO scholars to technology in an innovative and creative way. In order to achieve this, an exposition has been made about robotics. As an improvement on this, SETUP wished for an additional piece within the exhibit that would engage the scholars in ways previously unattainable on which this report will elaborate.

Chapter 2

Organisation

2.1 Project Description

In assignment of SETUP, an addition has to be designed and created for their exposition considering robotics. The product has to be engaging for VMBO-scholars, and should increase awareness of the idea of anthropomorphism regarding robots, and should provoke thinking about ethical debates surrounding robotics. This includes topics such as whether a robot should have rights like humans do, and what roles robots could play in the future. Apart from being a fun experience, it also has to prepare them for later on, as it is likely that their jobs will involve robotics, whether it will be a case of robots taking our jobs, or a robot performing a function complementary to human labour.

As a solution to this, Team CID (the team name under which this assignment was carried out) has created an arena that is marked by three differently coloured pillars, and is covered with snow (foam pieces). Within this environment, 6 small beetle-like robots drive around and push the snow away in order to clear their base. By doing so, however, other bases may get covered by the pushed away snow, which makes the robot to become agitated. This is where the children come into play, who are supposed to solve the issues by either moving it or petting it to make sure the robot resume their original tasks.

2.2 Team Composition

Team CID is a five-person-team, consisting of students from both the Universiteit Utrecht, and HKU. The corresponding members, their studies, and their main roles within the project are as follows: Collin Kasbergen (Interaction Design; physical development), Sascha de Waal (Game Development; physical development), Kris van

Geel (Interaction Design; management and design), Ishdeep Bhandari (Game and Media Technology, computer/robot vision), Ward Bannink (Game and Media Technology, robot intelligence).

As the team was rather multidisciplinary, there were a lot of possible approaches to consider. As it was unanimously agreed upon that every member should be able to work on something they like and are proficient with, the resulting product features something of every discipline the team members have to offer.

One of the teammates Collin Kasbergen was not able to continue the project during the mid June 2018 due to a medical condition. This meant that his tasks were divided among the team, to keep the overall structure of the project intact.

2.3 Planning

See the appendix A. There was an initial rough planning that was drafted up during the initial stages of the project. Later on, when it appeared more work was needed than thought initially, and some started losing the sense of what was going on, the second planning was created. This one contained a more detailed list of activities that needed to be done for the project. This provided the team with a more stable view.

Chapter 3

Project Rundown

3.1 Project Description

The aim of the project is to provide VMBO-scholars with an educative, as well as an engaging experience that prepares them for the future, done through development of 21st century skills. The children should be able to form a more concrete idea of robotics instead of the tin man concept that usually dominates their peers. This idea should include topics such as the uses and possibilities of robotics. To facilitate this, they will be introduced to the various skills of robots in a societal setting. Ideally, the project should also be adaptable to a new experimental method of teaching, to be executed by Globe College in Utrecht.

3.2 Research Questions

- How can we engage VMBO-scholars and keep them engaged?
- How can we induce thinking about specific topics (ethical debates and anthropomorphism in robots) in VMBO-scholars?
- How can we make the exhibit accessible to a variety of children with different preferences?

3.3 Hypothesis

The children can sketch an image about the possibilities with robots by being introduced to their various skills in a societal environment."

Chapter 4

Concept Development

4.1 Related Work

Since the project was more something of a research project into developing a new product, there was a lack of the usual type of useful information. Not much research has been done on VMBO-scholars, which is understandable since its a large part of an ever-changing society. One might only be able to capture the essence of part of their being in a given timeframe, which may become invalid within a year or two. While there was certain research available considering the performances of VMBO-scholars at school, knowledge about social behaviour was also required, and happened to be more important. Therefore, the team conducted its own research into the target audience.

Some relatable products were able to be found, however, which were used as a source of inspiration. There already exist a variety of robots today, used for social, practical, educational, or business purposes. The target was something that would be intended for children. As a result, we came across products such as Sparki (which is used in multiple schools for learning children how to code), Nao, Pepper, and Romeo (highly advanced robots capable of various forms of social interaction, and Cozmo, who is intended to be a playful friend for a child and which has its own quirky personality and is capable of showing eye-based emotions through a screen.

4.2 Target Audience

As the final product was intended to be used by VMBO students, it was important to investigate what sort of people had to be dealt with. Not only education-wise, but also on their attitudes, opinions, interests, and more, in order to make the product not only effective, but also appealing. A lot of work was done gathering information about all things typically VMBO. Even though it is difficult to gather reliable information surrounding a large group of individuals based solely on what level of secondary school they go to, information was obtained on what the typical VMBO student is like at school. This was done through multiple excursions for Team CID at various VMBO colleges in order to gather information on the VMBO scholars. The main results (not so much actual results as general tendencies) were as follows:

- Difficulties in working independently
- Hardships when having to judge the legitimacy of information sources
- Relative large need for clarity; e.g. when making exercises.
- Larger emphasis on status and social contacts

4.2.1 Gerrit Rietveld College

In order to get to know the scholars better, a visit was paid to the Gerrit Rietveld College in Utrecht. It was allowed to make observations of the students during one lecture. Two teams of two were made, one of which joined the societal science class, and one joined the English class. The main observations were that the kids had a lot of energy, a short attention span, and made a lot of use of the knowledge of their peers before asking the teacher. Apart from that, they did seem motivated to learn, or at least participate in the lecture. The interviews that were carried out afterward also reinforced these findings; the scholars found social ties to be very important; asked each other for input; and tended to get distracted.

4.2.2 Christelijk Lyceum Veenendaal

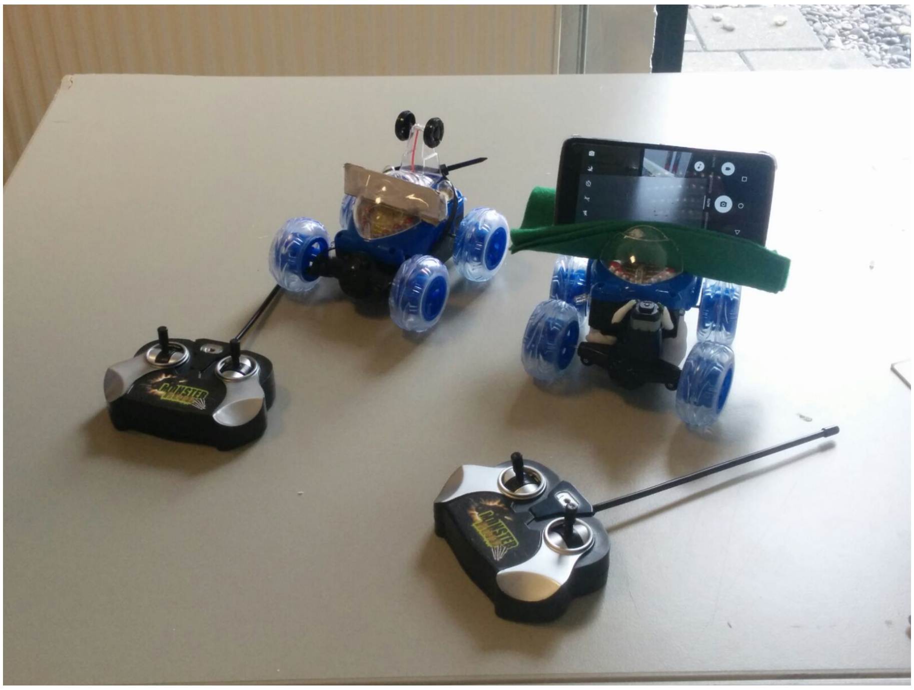

Figure 4.1: The First "Prototype"

For further gathering of information, a meeting was scheduled at Christelijk Lyceum Veenendaal where another experiment with VMBO scholars was to be done. This was done to discover what the kids already knew and thought of robotics, and to spark some interest. To do this, two RC toy cars were bought and modified to be able to carry a mobile phone, that was to be used to provide visual feedback that the children would see on a laptop as it drove around. The kids could see from the robots perspective through a laptop located in the classroom.

The class was split in two groups, with each being assigned its own robot that was hidden somewhere in the school. The children had to (vocally) say commands to the laptop connected to the phone on the robot in order to make the robot do something. In reality, someone held the remote control to steer the robot and could hear what the kids said. By working together and deciding what path the robot should follow, they had to guide the robot back to the classroom.

In practice, the groups were formed based on gender by the kids their own choice. The experiment wasnt well-received, it being considered very childish, boring, senseless and lame. Most of the time commands were shouted across each other, causing the robot to become confused, which caused the kids to further distance themselves from the demonstration. The presence of lag causing the person controlling the robot to hear the commands some seconds later also had a negative impact.

Afterward, a discussion was started with the scholars on the topic of robotics, and their thought surrounding this. The reason for this was to create an idea of their method of thinking, their knowledge of the subject, but also in how much theyre interested and willing to work with a topic such as this.

In the experiment, the girls had a more observing and structured way of working, whereas the boys took a more active approach to command the robot. The girl group also took the lag in the connection better than the boys, who got upset. Furthermore, the boys werent very clear with their directions given to the robot, which caused the controller to sometimes make the robot behave in a way they didnt expect. This was immediately labeled as bad behaviour by the kids, who put the blame on the robot.

During the discussion, it became apparent that overall, the kids havent had any experience with robots before, only possibly having gathered information from media such as movies. The majority of the kids were in agreement that you couldnt become friends with a robot, they cant have any actual feelings, should serve humanity, and are only allowed an opinion if this is in line with their intended purpose. Another recurring topic was the cooking and serving of food. Apart from that, the view on robots were more negative than positive, as they expect them to take their jobs, and maybe pose a danger to humanity in the future.

Something worth noting, is that the kids had troubles with conceiving what-if scenarios, come up with their own examples, and to create a look into the future. When presented with an example, though, they could discuss it for a small while before there was nothing more to say. Apart from that, it was very apparent that the kids were held back by their own social culture they had to conform to. There were a small amount of kids that took the lead in an opinion, and the rest swiftly followed. This was combined with a general disinterest of a lot of things, laughing at each other for having a slightly off opinion or preference, and being afraid to be left out of the group.

4.3 BeetleBots

During the start-up of this project, a lot of different concepts were conceived to filter out the best parts and ideas. Various brainstorming techniques were employed in order to do this, one of which was centered on animals. Given an animal, ideas had to be conceived within a certain time. Joint brainstorming sessions also have been had, and various mindmaps were made in order to better understand the possibilities surrounding the project.

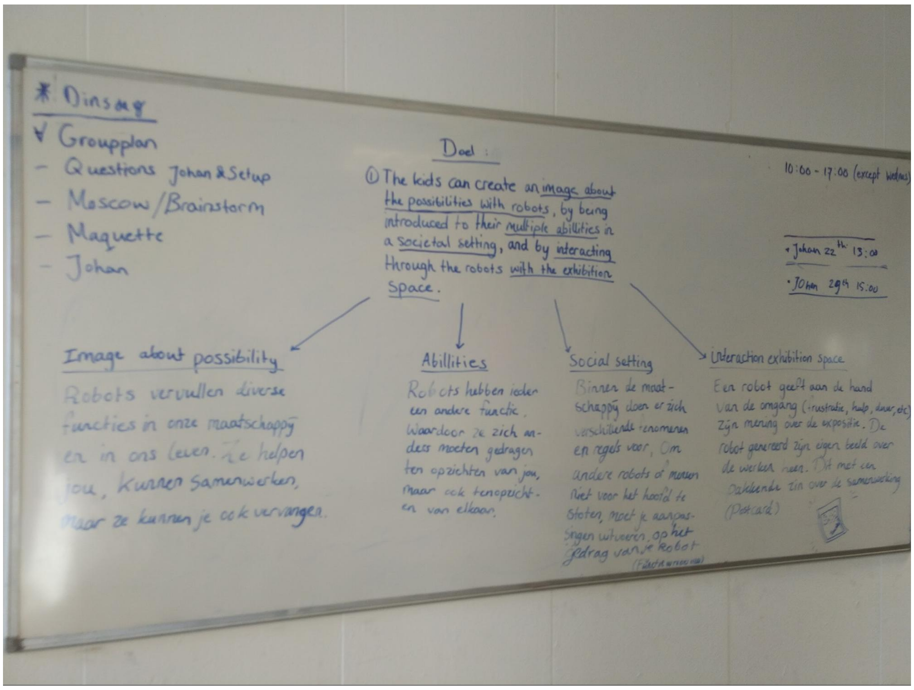

Figure 4.2: The framework from our target research, divided over different levels of depth.

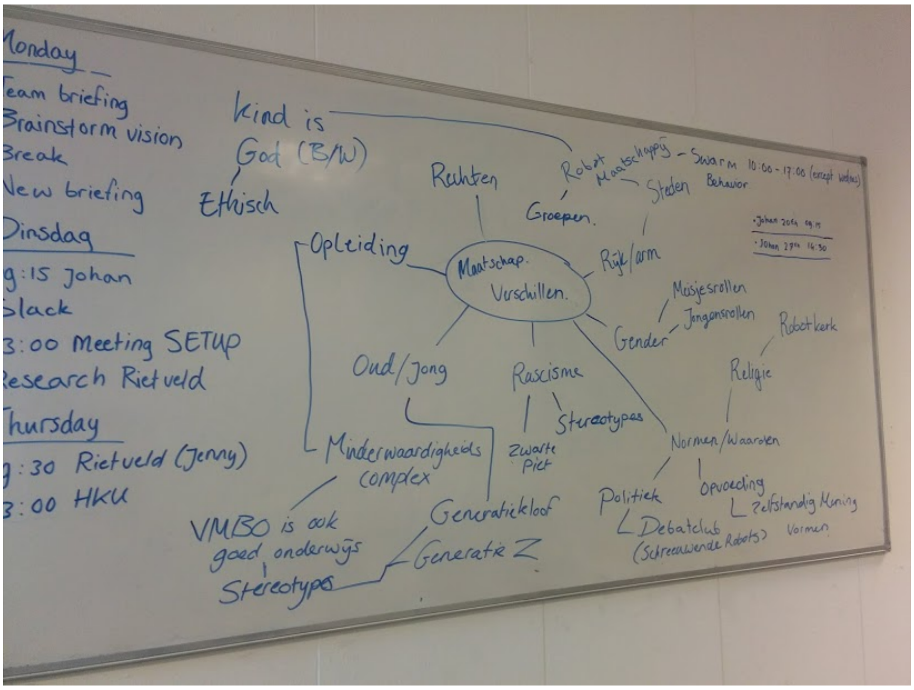

Figure 4.3: Brainstorming on the basis of information from Set-up and attending the Perfect-Storm conference, where a co-creation session was held with teachers and the team of Setup.

Figure 4.4: Scale model used to show an interim idea about using the entire space. The robots drove through the floor parts under the people, instead of employing the ground floor the people used. In the corridors in the floorboards, children could help the robots solve puzzles.

4.3.1 Concept

Within the Yurt in the creative lab of SETUP there is a plateau with a large amount of 'snow'. In this snow there are 10 to 15 robots that each belong to one of the three groups (colors). All these robots have the task to build the largest possible mountain together with their group, within their territory, with the snow in the room. However, these robots, because they are building the mountains, also want to have snow from each other, after all there is only a certain amount of snow.

As a result, the robots become increasingly frustrated towards each other, because their mountain is consequently being demolished by the other robots. The robots are thus slowly becoming increasingly aggressive towards each other and will perform their task ever worse, because they are sharing in an increasingly violent conflict. They will try to push each other over, cross trees, and in this process completely deviate from their original task, as a result of which hardly any mountains are built.

It is up to the children to get these robots out of their conflict. The robots need comfort, care and cooling to be able to function as originally intended. However, it is up to the child to figure out if the robot has to be stroked, cuddled, kept warm or simply having to load it. When the robot has calmed down again, the robot can be put back to his group, to pick up his job again and repair the damage.

4.3.1.1 Layer / Phase one - An image of the possibilities

"Robots fulfill various functions in our society and in our lives. They help you, can work together and can also replace you. "

This phase is the phase of the simple execution of mountain construction, which the robots start with. At this moment the robots are still blank, so they simply perform their task. They push the snow to the place designated for them as their territory, and simply try to make the largest possible mountain.

Because showing the very practical 'task-execution' of a robot, as it is now known in various factories, we hoped to give the children a new image of what a robot actually does and what that could be for example . Our research has shown that these young people have little to no idea of what robots actually are (the clich of the 'tin-man' aside).

4.3.1.2 Low / Phase two - Skills of robots

"Because robots have different functions, they have to behave differently to each other but also to you"

This is the phase in which the origin of conflict is presented. The robots all have the same function, but they also appeal to the same raw materials. The robots start stealing (unintentionally) from each other.

This is the point where anthropomorphism actually occurs. Because in a normal scenario, the robots would forever steal back and forth from each other and there will be no reaction. However, the robots do respond to us. The robots get frustrated with each other's actions and thereby rise up. We forced an 'anthropomorphic' view of the object through an unexpected 'human' response from the robots.

4.3.1.3 Low / Phase three - Social setting and conflict

"Within society, there are various phenomena and rules to avoid bumping into other robots or people. We are asked for social adjustment "

This is the moment that the child comes into action. The robots no longer perform their tasks and are in a deep conflict with each other. It is therefore up to the child to see the robot calm down in one way or another. For this we offered three different 'animal / human' interactions that have to be applied to the robot to calm him down and get him back to a functional state.

We wanted to use petting, cuddling and charging. These will each be made measurable by various sensors. The child has to pick up the robot from the large platform and place it in the charging stations, as it were, to satisfy the needs of the robot. Once the robot has calmed down, the robot can be put back in order to strengthen his team again while winning territory.

In this phase, the children are forced to approach the robot both interactively and mentally differently than they intended in the first instance. We hoped to create a kind of 'tamagochi' effect, in which the children take care and conflict resolution towards the robots.

4.3.1.4 The Cycle

This concept has no end, as can be seen. The robots will always be in conflict with each other because of the conflicting interests. The children can therefore come back any moment and get started and do what they want. This way we hoped to stimulate some experiment and creative thinking with them.

Figure 4.5: A representation of the concept

Figure 4.6: A represented explanation of the final concept

4.3.1.5 Feedback Setup and Johan

- It is interesting to look at a machine-learning option with the robots, which could make an interesting long-lasting experience (starting with the tamagotchi effect as discussed).

- Shoveling snow is probably more interesting, given its conceptual values. 'Literally shifting from one problem to another'.

- Look at board games for interesting game mechanics with reference to having a bigger picture.

- Try to iterate the behavior of the system for any interesting outcomes.

- If necessary, deliver a clear basic plan for the robot.

- Cuddle mechanic too sweet and feminine, see if other interaction possibilities are possible with an eye on the target group.

4.3.1.6 Follow-up steps from team CID

- We provided an interim budget with which we can build a scalable prototype. We had put this on 6 robots, divided over 3 teams, in order to be able to test the basic cycle. With this, we hope to have more certainty about delivering a working prototype to later scaling up in various ways. The spatial aspect of the installation (the plateau + single dockings) are included.

- We thought that the idea of shifting snow instead of collecting fits well with our concept and we want to continue this for now in the iterations on our concept.

- In the coming weeks we would deepen our knowledge of game mechanics that could make the current experience more interesting.

- We deleted the hug interaction and replace it with a more masculine interaction, with an eye on the target group.

- At that moment we did not dare to promise anything to adapt machine learning to our current concept in the longer term. After consultation, we consider this still unfeasible, but we were certainly prepared after building the core of the concept to still look at the possibilities.

In the final concept, unfortunately, a number of things have been canceled due to the circumstances and their aftermath. For example, we have conceptually replaced the cuddle interaction with sabotage, in which boys are also more involved. The robots hit each other, but the children can also choose to sabotage the robots. In the end, we only produced a proof of concept, which did not meet all the demands of ourselves, but given the resources we had, we gave everything we could.

Chapter 5

Approach

5.1 Raspberry Pi

Raspberry Pi has been famously used in designing robots chipsets due to small size and ease of use. In this project, Raspberry Pis will be used for running the onboard camera, the motors turning the wheels of the robot, and for running an onboard speaker. Also, an arduino chip would be attached to a Raspberry pi for further functionality.

5.2 Arduino

The Arduino chipset used in each robot would have light sensors, lithium battery (for powering both the arduino and raspberry pi), accelerator, and a gyroscope for direction. All this input would be fed into the Raspberry Pi which in turn would be sent to the the computer to add further functionality. This allowed us to use a multitude of sensors that we wouldnt have access to with just the Pi. Especially the gyroscope was of critical importance as it was the only component that allowed some form of navigation. In this case, this took the form of tracking the amount of degrees a robot was turned from its starting position.

5.3 Object Detection

Object Recognition was implemented using YOLO darknet library where the robots would be trained to differentiate between 3 differently colored (Blue, Yellow and Purple) robots and bases. Since the robots get agitated when they see an opponent thwarting their goals, it was imperative that they would have some means of recognizing whenever this happens. Object detection was the answer to this issue.

5.4 AI Structure

In order to imitate having a personality, a robot would have certain behavioural parameters that indicate the presence of some emotion, or the opposite of said emotion. For example, boredom versus excitement. These parameters determine how the robot feels, and thus what behaviours it exhibits. A robot that is very scared will attempt to hide from the user, for example. The way these parameters work is that they contain an integer value that indicates a score on a spectrum between two opposite emotions, with a higher value indicating the more positive side of the emotion. In order to determine when the robot crosses the boundary from one side to the other of the spectrum, a separate threshold value exists. With this, it is possible to create different personalities for a robot, as one could be more easily irritated than the other. In our case, however, we only need to have a calm vs aggressive parameter, as the robots will either be in a calm state in which they push snow, or in an aggressive state in which they perform aggressively.

While this initial idea has to be replaced by something less convoluted (explained below), the base idea remained the same. Robots contain an arousal variable that indicates the level of anger for that robot in specific. This arousal can increase whenever it sees an opponent at its base, and decreases when being pet by a child. In order to account for the wide variety of states a robot could find itself in, and the possible tasks it had to do, a state-based approach was taken. Apart from allowing certain state transitions to be made, the level of arousal also influenced the general behaviour of the robot. The more angry it was, the more aggressively it drove around. The used and implemented states with their explanations are as follows:

- AngeredState; a state in which the robot performs an angry dance. This state can only be reached when the arousal is above a specific level, thus requiring the robot to first actually become agitated.
- AttackBaseState; the robot seeks out one of the enemy bases, so one that doesnt have its own team colour. Once found, it tries to place itself in such a way so there is snow between it and its target. After doing so, it proceeds to push the snow towards the foes base. Afterward, it transitions to the ReturnToBaseState.
- BeingPetState; the robot is being pet in this state, which is determined based on the input received by the light sensors. If the sensors pick up a somewhat dark environment for 3 seconds, the robots arousal will decrease. It remains in this state until the robot isnt being pet anymore, once again determined by the light sensors.

- RemoveSnowState; while at its own base, the robot tries to determine a path that includes pushing away snow, but not towards its own base. This is done through detecting its base with object detection. If it cant see the base, but it can see snow, it will push the snow away. Whenever it sees the base, it makes a 180 degrees turn and starts to look for snow. After some random amount of time, it will make a transition to AttackBaseState, so that all robots take turns in defending and attacking.

- ReturnToBaseState; initially looking around the environment to see whether it can find its own base, the robot will drive towards the base when found. Once back at its own base, the robot will position itself in such a way that it can begin pushing snow away from the base. This is done through the same method as above by making sure there is no snow between the robot line of sight and its base.

- ShakenState (which occurs after a child violently shakes the robot; assumed to be a highly likely scenario) in which the robot drives around in a dizzy manner. The pattern in which it drives around is randomly based on one of 8 different ways to move, including a bias towards powering the left or right wheel to make it move in curves. It will keep moving in one of 8 manners for a random amount of seconds. While doing so, it will slowly speed up the longer it keeps moving in the same direction.

All of these states extend the BaseState, whether directly or indirectly. In the BaseState all the base functionality is being run. This includes things such as determining to what state should be transitioned. Further functionality includes collision avoidance between robots and bases, and providing accessibility to various variables.

Furthermore, in conjunction with object detection, a robot keeps track of what other team is shoveling snow into its territory the most. This is to create rivalries or dislike towards one team in specific, in order to create more believable behaviour. As all robots can eventually become red due to being in an angered state, however, chaos will ensue and no one will know whos with who anymore.

Chapter 6

Implementation

6.1 Materials used

6.1.1 Hardware and Building Materials

- PETG Vivek
- PLA
- Plastic Foam Pieces
- Arduino
- Raspberry Pi Zero
- Alienaware 15 inch Laptop with quad core 7700hk, 16 gb ram and GTX 1070 (Server)

6.1.2 Softwares and Languages

- Python 2.7
- YOLO mark
- YOLO darknet library with executable
- Linux debian
- Windows 10
- Pycharm
- Cuda 9.0
- OpenCV 3.2
- Raspberry Pi 3
- Flask

6.2 Contributions

6.2.1 Ward

Involved with the designing of the product in the first half (designing phase) of the project. Thought of multiple possible directions to go into with the project (such as a concept where robots traveled through tubes that were laid out throughout the room as means of transportation to various stations where interaction was possible with children), as well as helping out with the various types of research. Among others, these included investigating what our target audience was, and how to approach them. This was theoretical research, as well as practical, which took the form of visiting schools to interview and observe our audience, and performing experiments with the children and robot toys.

In the second, more practical part, focused mainly on the AI, movement, emotional states, and other behaviour of the robots. But apart from that also helped out Ishdeep with object recognition (such as creating training data, and working on the code), as well as aiding other teammates with more practical handiwork, including the staining (some sort of painting) of wood. Also made large contributions to the report.

6.2.2 Ishdeep

Involved with the initial designing phase to compress the initial idea of the client to meet realistic standards. Introduced many different ideas in collaboration with ward, that would be most technically feasible. Also, was responsible for conducting research in finding earlier implementation of robotics to engage children. Along with this, participated in conducting target audience research with Ward and the team.

During the implementation was involved in creating an object detection model, to detect the bases and other robots, in order to avoid collisions. Also, use the model to help robots traverse the environment using AI. Moreover, helped to build wood platforms for the robots and helped ward in connecting the object detection and AI implementations.

6.3 Implementation

6.3.1 Physical Development

The physical development of the concept consists, as it were, of three parts: the arena, the robots themselves and the bases, to which the robots belong. Various types of plastics have been used, and wood has been used to construct this arena.

6.3.1.1 Arena

The arena is a wooden plateau of about 200cm by 300cm (292cm), which is made to measure for the Yurt, where this installation would be placed. 18mm poplar plywood has been used to provide assurance of strength. Even if it is not intended to be walked on, the platform is made so that it can still be safe. After all, adolescents remain unpredictable.To finish the wood, use was made of a stain (douglas inhibitors, also impregnating). In the construction underneath the platform a cable diversion is made, so that the bases can be connected, without visible power supplies. In addition, the bins are equipped with cutouts, making them easier to lift and move. Lifting and moving on your own is not recommended.

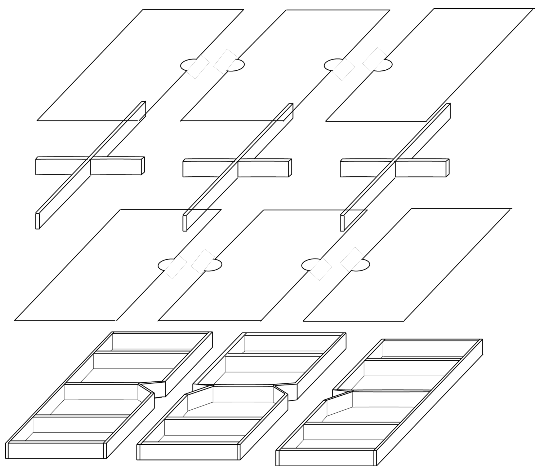

Figure 6.1: Original construction drawings and floor plan Yurt (final design has been modified)

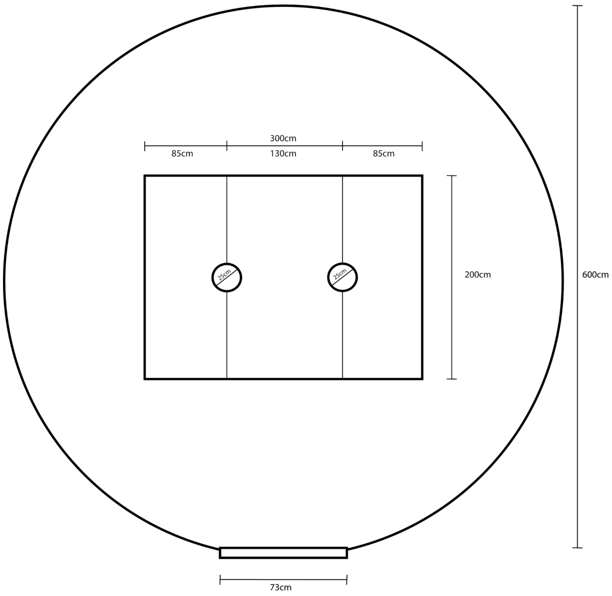

Figure 6.2: The final design of the area

Figure 6.3: The implementation of the final design

6.3.1.2 Bases

The bases are simple opal poles, with neopixel LED lighting. The posts are made of Vivak opal 2mm (PETG) and glued and secured with corner pieces and bolts and nuts. The bottom is also attached to the arena with corner pieces, which are easy to remove. In addition, the top is detachable, to keep the electricity accessible during use and possible repair. The neopixels are controlled with an arduino nano that can be reprogrammed and connected directly to the power socket.

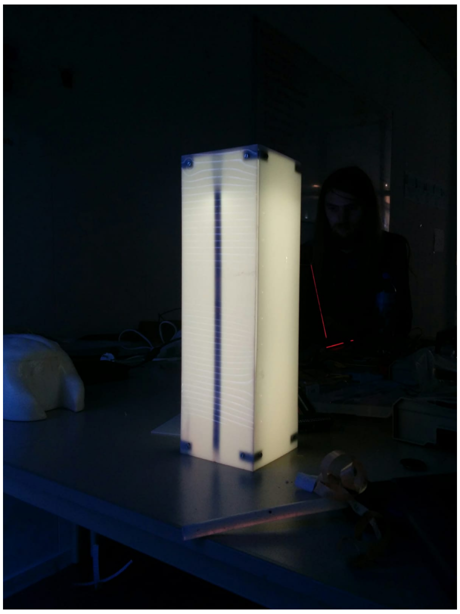

Figure 6.4: Final Design of the bases

6.3.1.3 Robots

In addition to the complex technical construction (circuits, AI, color and object recognition), most of the components on the Beetlebots were originally designed by team CID and executed. The bottom plates (where on / off button can be found) are made of Polycarbonate. This can possibly be replaced by a more flexible material (such as PETG Vivak, which has also been used for the caps). The caps are from opal 2mm Vivak, just like the bases. However, the caps have been thermoformed over a handmade mold of modeling foam. The last mold is still intact, which means that new caps can still be made for repair (two previous molds have unfortunately been killed in the process).

Each hood is custom made, due to a few milimeters difference between each robot. This means that not every cover fits every robot (this is important for both the sensors and the camera). This difference is due to the bonding of the technique, and the use of different molds, which were not identical. The robots have a feature that shows which hood belongs to which bottom. The caps are secured with corner pieces, bolts and nuts, the lower bolts of which are glued.

The skeleton of the robot (the arch where the sensors and the camera rest on) are printed from PETG, which means that these arches, like the caps, are very flexible and will not break easily. Also half of the ball holders and the wheels of PETG. Some individuals can still find ball holders and wheels that are printed in PLA. This means, due to the rapid drying out of PLA, that they will eventually have to be replaced by ball retainers and wheels of PETG (or another flexible filament)

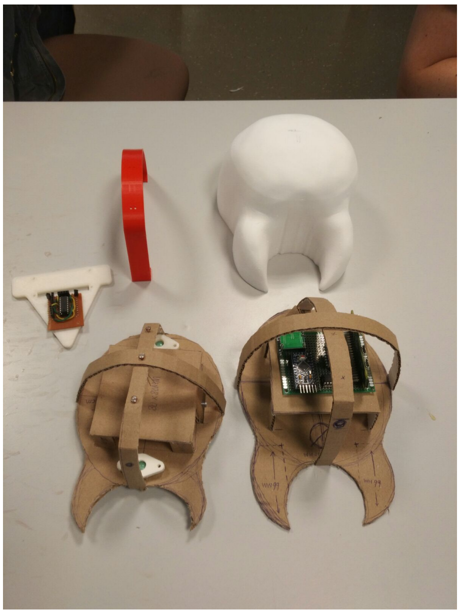

Figure 6.5: First Conceptual Models

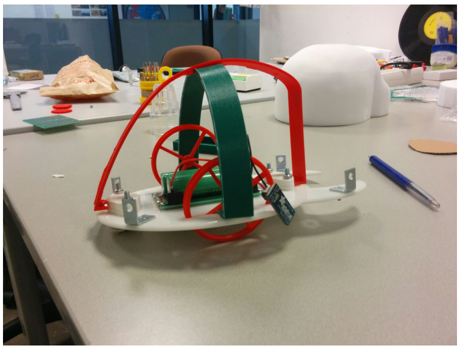

Figure 6.6: First version skeleton and set up mechanism. The middle arch has been removed due to space lack and uselessness after the removal of the heat sensors.

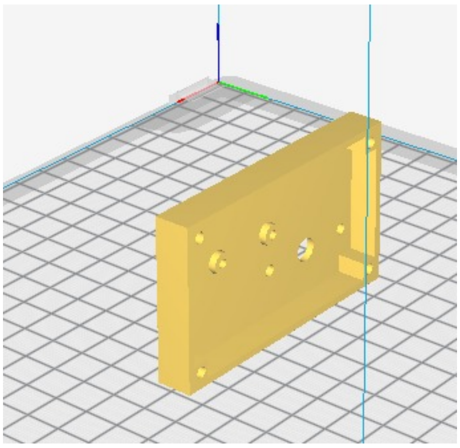

Figure 6.7: Version of the original intended gearbox for the robot. The gearbox ensures that the wheels move with the motor drive. Designing of such a gearbox turned out to be such complex that eventually a prefab was chosen for the Gearbox.

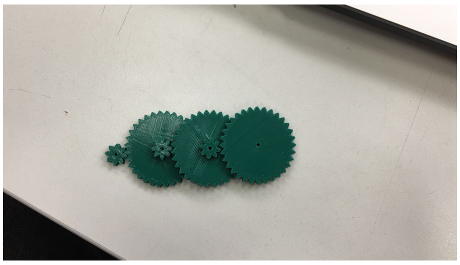

Figure 6.8: Gears for the above gearbox. Also designed and printed in PLA. Not even in it final model come.

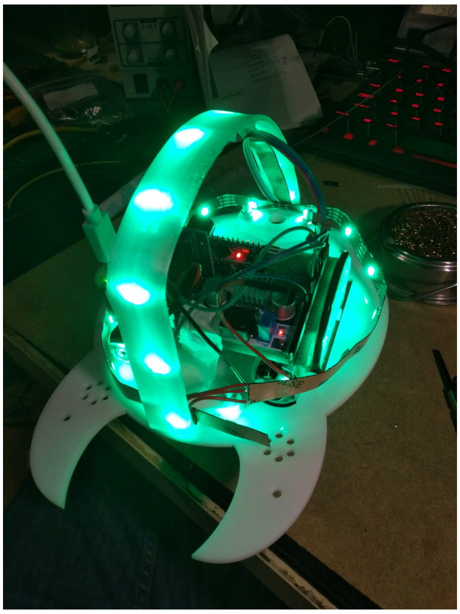

Figure 6.9: The second-to-last version of technology in the robot. Due to current shortage, there are fewer LEDs in it when compared to the latest version.

Figure 6.10: Closed robot without drilled sensors and camera.

For more information on the 3d files please see the Appendix A

6.3.2 Object Detection

6.3.2.1 Darknet

YOLO darknet is an open source object detection library built using Convolutional Neural Networks (CNN). CNNs are built to analyzing visual imagery using feed-forward artificial neural networks.

The CNN works by applying a filter to an image and deriving a new image which will pass through some activation functions to generate weights that would be passed through neurons, this is a Convolutionall layer. A fully connected layer then, connects all the neurons from the Convolutional layers to output the trained classifier. This constitutes of one iteration, which also includes an average learning rate parameter which must be tracked to see the progress of the training.

Darknet includes various combinations of these layers under configuration files. Some include a great number of layers to train more efficiently and quickly but they come at a cost of computational power requirements, whereas some have only a few layers to train on lower configuration systems; thus increasing training time. So, for this project to train on the Alienware laptop we modified and used the tiny-yolo configuration, which involves only a few layers.

6.3.2.2 Preparing Data

The images used for the training were extracted from videos recorded for each colored robot and base. About 1000 images were used for training. The images must have the location of the object to be found in each image. This was done by using the YOLO Mark software to manually created bounding boxes where the object was located, thus creating a txt file with the location information. Here, the class to classify the object was also included. For instance, Blue colored robot was RobotB, Purple Colored base was BaseP etc. Then, all this information must be added to the darknet folder that allowed it to access it during training.

The videos (extracted images) were recorded in low and medium lighting (at 720p), but the yurt where the final exhibition would be held inside, has low lighting. So, this would help in avoiding an discrepancies in the predictions if the lighting changes.

6.3.2.3 Training

The training involved a number of steps, which are as follows. Darknet has some dependencies to be installed before starting the training; namely; Opencv 3.2 and Cuda 9.0 (This was only used to speed up the training). Cuda is an Nvidia software that allows to use the graphic card's v-ram memory to store images while training. Darknet has pre-built executable to start the training information. The information provided to the executable were the images, number and name of the classes, modified yolo-tiny configuration file and the initial weights assiciated with it. The training was stopped after 12000 iterations as the average learning late for the training stopped reducing. The output is a set of weights that would be used in the predicting.

6.3.2.4 Testing

At the robot Side, using flask a networking library in python, each robot would transmit one frame per request by hosting it on a local host, which in then would be retrieved at the server by using the requests python library. Once, the frame is retrieved for each robot, the darknet detector runs using the final trained weights and the yolo-tiny configuration file to predict all the frames simultaneously. The output of the detector is an array containing the type of object, the prediction accuracy, it's location in the frame and the width and height of the bounding box exclusive to each robot frame. These values are passed using the flask library back to the robot and saved in a txt file to be retrieved by the AI code.

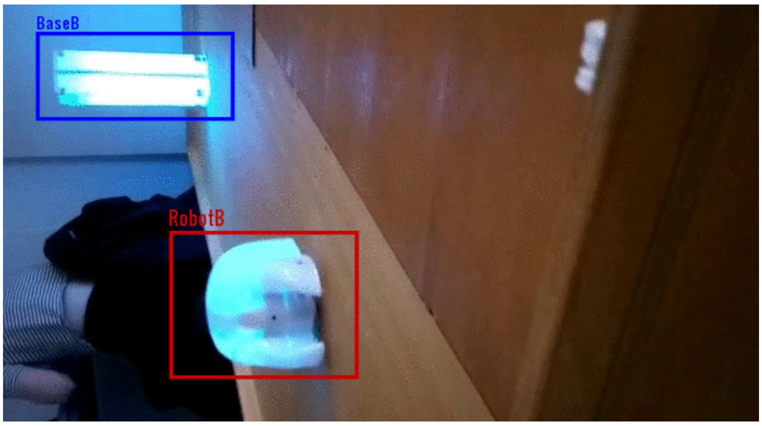

Figure 6.11: Example of a predicted frame.

All AI and object detection programming done on the robot was implemented on the raspberry pi zero installed on each robot

6.3.3 Raspberry Pi Zero

After looking into many a different robot, we arrived at the Raspberry Pi, a very modular computer that comes relatively cheap. This was a certain plus, since we aimed towards creating a colony of robots; requiring more than a handful of robots. Furthermore, it provided the option of attaching a camera to the motherboard, which was essential for object recognition and colour detection. Besides that, it was also very modular, which allowed us to couple an Arduino to it in order to employ a multitude of sensors, as well as write our own custom code for the robots.

6.3.4 Arduino

Since the members of our team whod work on the hardware of the robots already had some experiences with Arduinos, the choice wasnt hard to make. The price was relatively low, and there were a lot of options for additional sensors to provide the robots with. Another important point was that the Raspberry Pi Zero didnt have analog read, and while it was possible to get additional devices to enable this, it would be more expensive than the Pi itself. The Arduino solved this problem.

The Arduino powered the two motor pins that were used for robot locomotion. In order to be able to influence these motors, the DriveMotor class was created, where a connection exists from the code on the Pi to the connected Arduino. From here, the rotation direction of the motors, and the speed at which they turned could be set. Likewise, the ArduinoBridge file was created for the Pi in order to receive the sensor output from the Arduino. This was done by writing the data from the Arduino to a JSON-file, which was then read by this ArduinoBridge file, in order to have access to the data to be used by the behavioural code.

6.3.5 Gyroscope

Soldered onto the Arduino, the gyroscope provided the robot with a sense of direction, and also functioned as accelerometer. It could sense the G-forces in x, y, and z-directions, as well as the degrees turned about those axes. The gyroscope was essential for the functioning of the robot, as it provided the data that led to the transitioning to various states. For example, when a robot is picked up by a child and shaken violently, the delta of all the accelerometer axes compared to the previous frame allow the robot to make the transition to the ShakenState from whatever state it found itself in initially.

6.3.6 Light Sensors

Three light sensors were placed on the top of the shell of the robot. These functioned to detect whether a child was stroking or hugging the robot, which resulted into a decrease of the arousal of the robot.

6.3.7 Camera

The Raspberry Pi already supported the use of a camera, which made it easy to attach one. Because the core of the input for the robot consisted of detecting objects and colours, a camera was a necessity. Its used to detect snow (either to be pushed away from the own base, or towards an enemy base), robots, and bases.

6.3.8 Artificial Intelligence

As the premises of the project included topics like identity and anthropomorphism, it was decided that giving the robot some form of emotions would be a fitting addition. While initially the idea was to use a wide range of emotions that were laid out on a positive affect versus negative affect scale, this appeared to be redundant later on.

The idea was to have each child take care of a single robot in order to appease it. The robot would then provide the child with feedback about how it felt towards its caretaker based on these emotional scales. When it was opted to go for a more colony-esque approach, these scales werent necessary anymore, and only the arousal level remained, as the robot could now only become either upset or calmed down.

A state machine was chosen because the robot needed to operate in a variety of states. Most of these would employ similar functionality, and thus all extended from one BaseState that offered basic functionality. A DriveState extending this BaseState was created for the implementation of all the movement-related functionality. This state was then extended by all the states that used some form of movement, namely the AngeredState, AttackBaseState, RemoveSnowState, ReturnToBaseState, and ShakenState. The state machine kept the hierarchy of the states understandable and efficient, also preventing duplicated code in the program.

For the code files please see the Appendix A

Chapter 7

Testing

Testing the robots occurred mostly internally within the room that was assigned to the team for this project. It involved running the object detection on all the robots while maintaining constant stream to the server. Also, debugging the movement code to see how the robots were moving in the arena and at what speed. All these tests were run on the arena to see the feasibility of the same and how to avoid the robots getting stuck in the 'snow' foam pieces.

Chapter 8

Evaluation

8.1 Limitations and Problems faced

8.1.1 Design and Implementation restrictions

The initial idea was to order pre-made gearboxes and boards that would be used to run the robots. But the team member working on the hardware suggested otherwise and went on to build his own board and gearboxes. While designing the boards there were a lot of problems and were left unfinished as the team member feel sick and had to leave the project. This left the robot boards not optimized for usage and had to rectified.

The design choices for the project were made in keeping in mind an economical budget, which led us to choose the materials used. Moreover, due to the initial budget restrictions the cheap circuits used for production were of low quality and power. This compromised the running of the AI and the object detection efficiently.

8.1.2 Object Detection

Initially the idea was to use tensorflow google's free to use object detection API. But, due to its poor support on windows and server authentication problems on Linux, it was discarded. This required a lot of trial and error, to find out missing files or bugged out installations. Moreover, to the unavailability of a powerful desktop to train the object detection algorithm increased the overall time to implement the object detection.

8.2 Results

Although the initial goals were a lot higher than what was ultimately accomplished, the team still was satisfied with what had been accomplished, despite all of the setbacks. The final product consisted of a square wooden plateau with slightly raised edges to prevent the robots from driving off the structure. There were three rectangular bases with LED lights that shone in one of three team colours. The robots, most importantly, were able to drive around in a semi-random manner on the field. Transitions were able to be made between the idle state, angered state, and shaken state, in which the robots LEDs shone in the colour of their team, red, or flickered between a variety of colours, respectively.

During the showcase, two of the robots randomly drove around on the plateau. Sometimes, they pushed away snow, or were spinning around their own axis for a small amount of time, and at other times they drove headfirst into a pile of snow, only to subsequently get stuck. It was noticeable that the shell of the robot might have been a bit too high off the ground, as the snow peanuts tended to slide underneath the shell, causing the robot to get stuck. Despite the lesser amount of progress reached than intended, people did seem to like the way the robots behaved, and found them inviting to play and interact with them.

The object recognition worked very well, reaching an average accuracy rate of 70% within small amounts of time (about 4 seconds) with a detection score range of (60-100%) Unfortunately, it was impossible to integrate the object recognition within the behaviour of the robot, due to time constraints. The building blocks are there, however, and a lot of functionality can be created with the combination of the behaviour and recognition.

8.3 Analysis

The day before the demo, it used to be possible to shake the robot in order to transition to the shaken state, but this later turned out not to be possible anymore, as the gyroscope and accelerometer either seemed to be broken or to measure something else entirely. In the latter case, it seemed to measure how much it thought the robot was going to accelerate, as we got higher measurements when the robot sped up or turned. However, this sensor didnt pick up any changes when the robot itself was shaken manually. Therefore, it was opted to randomly alter between the three behaviours, in order to show that various behaviours were possible, even though not fully distinctive from each other based on how the robot behaved.

Even though there were three finished robots initially, the showcase had to be done with only two robots, since the third one had broken down. After a while during the showcase, a second one broke down as well. After analyzing the situation, it was determined that the Pi had gotten fried due to the higher load placed on it than it was intended for. Using the camera, sending camera data, driving the motors, performing object recognition, and employing the AI appeared to be too much for it.

8.4 Discussion

Despite the less-than-intended achievements of the project, it did seem to have its intended purpose during the showcase. (perhaps some info about during the demo at globe?) People of various age categories were interested in the robots, and found them very inviting to interact with. A number of onlookers also stated they found the robots to look very anthropomorphic. Even when all they were doing was driving around randomly, the behaviour still was considered to have some form of intellectual and emotional load attached to it. This is no surprise; as Heider and Simmel have shown, people are quick to anthropomorphize objects. This holds even for objects that hardly resemble any living creature, such as a triangle or circle. Since the robots were created to be reminiscent of a beetle, it was expected for people to see them for something more than what they are.

For some part, the lack of reliably-performing hardware prevented further development of the behaviour, as well as fixing the existing behaviour to includes things such as responding to being shaken. Since the available budget was intended to make a prototype, however, this was to be expected, as when one uses somewhat cheaper components, a product tends to become less reliable in general.

8.5 Conclusion

While less was achieved than was initially intended to, the team still managed to show something presentable. The robots were well-received by the audience, and performed reasonably well. Due to hardware malfunctioning, however, repairs and replacements need to be performed in order to keep the robots up and running.

8.6 Ideas for Future Work

1. Certain hardware parts will need to be replaced or added, preferably by something better and more robust. This mostly goes for the motors, which werent strong

enough to get the robot out of a pile of peanuts when it drove itself into one), the Pi, the gyroscope, and the accelerometer. Since the Pi generates a lot of heat, a cooling system is also desired, as the processor of the Pi overheated with multiple robots. Once this is done, more robots could be built with the reserve components in order to retain the idea of a robot colony.

2. Step-up boards are added to the circuit boards. This should not be the cheapest, because they cause too much fluctuation in the flow, causing the Pi and Arduino to reset itself. By using a slightly more expensive step-up, you will not be bothered by this.

3. In addition, it is sensible with a view to risk of fire and short circuit to let another hardware specialist look at the boards and the soldering work. Note: this may mean that large-scale changes may have to take place. We dare not say what these changes are.

4. In addition, the motors and batteries have to be glued and some cameras are still being drilled out of the external hoods. This can only be done when everything is in the robot. Then the camera can be signed off and drilled out. First remove hardware before drilling.

5. When gluing the motors, it is important that the wheels are attached and placed as far forward as possible, so that there is enough space for the battery trays. These too must be glued as close to the motors as possible, because the tabs of the caps still have to pass the hardware to be able to close.

6. The sensors, LED strips, and chargers must also be glued and soldered. In addition, the on and off button must also be drilled out and glued in three robots. This can easily be done with a drill press. It is important that the light sensors do not make contact with the LED strip, as a result of which a short circuit occurs.

7. Instead of using frames, use full video streams from the robot cameras as input for the object detection on the server. This would not only speed up the overall detection time, but also making real time detection would help in keep track of the results and will help the AI to make smoother movements. This would be possible by upgrading the hardware namely; the Raspberry Pi Zero (single core processor) to Raspberry Pi 3 (quad core processor).

8. After implementation of the remainder of intended behaviours, more behaviours could be implemented to allow for a wider usage. A possibility would be to train the recognizer to recognize hands, so that for example a child could wave to a robot, in response to which the robot flickers in green to greet the child back.

Chapter 9

References and Resources

1. Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *The American journal of psychology, 57(2)*, 243-259.

2. https://www.anki.com/en-us/cozmo - Cozmo

3. https://www.ald.softbankrobotics.com/en - Nao, Pepper, Romeo

4. http://arcbotics.com/products/sparki/ - Sparki

5. https://pjreddie.com/darknet/yolo/ - Darknet

6. https://github.com/AlexeyAB/darknet - Training Object Detector

7. https://github.com/AlexeyAB/Yolo_mark- Yolo Mark

Appendix A

Useful Links

1. For 3d print files see https://a360.co/2vCAwl
2. For Planning see the attached Files
3. For all code files see https://github.com/SaschaDeWaal/machina/tree/master