School of Science and Technology

Robotics project report: Project Dog

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Introduction

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Our group was given the assignment to create a prototype of a social robot. To execute a project to perfection one must first perfectly understand the aim of the project. Therefore we set out to understand what exactly was meant by "Social robotics". Science fiction has always been obsessed with the possibilities of animating the inanimate. Some examples of these incredibly popular fictional characters include Robby the robot, KITT, and perhaps most famously C3PO (Figure 1). Our research concluded that perhaps the easiest type of social robot to develop would be on that mimics the behaviourisms of a canine. We, therefore, set out to build a dog-like robot that would be able to interact with humans by using a variety of sensors.

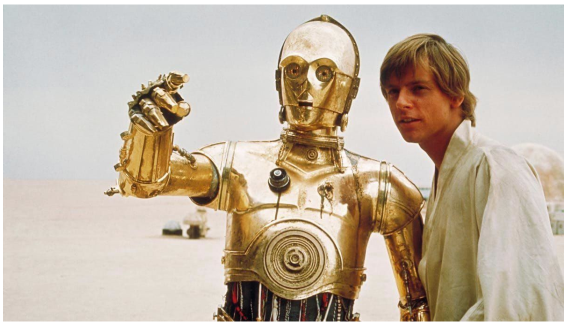

Figure 1. C3PO from Star Wars

Research

Besides the entertainment factor, these robots bring to a movie or TV show we theorised that there are perhaps alternative motivators to humanity's obsession with creating the sentient.

We will present to you two motivators we deemed interesting to consider when creating our prototype. The first obvious motivator is the literal act of creating a sentient being. Throughout religious scriptures and ancient texts, there have been records of a deity bestowing life on earth. There is perhaps something godlike about a species being able to create sentients at will. We considered this a major motivator in humanities relentless quest to create the first sentient robot. Our obsession has gotten so in depth that there are tests and rewards for creating such a robot. The Turing test[1] is perhaps the most popular of tests to judge a robots sentients. It was proposed in 1950 by famous mathematician Alan Turing to test a machine's ability to exhibit intelligent behaviour that is indistinguishable from that of a human. At the time of writing this report, no such machine has been able to pass the hardest section of the Turing test. The Loebner prize[2] is an annual competition that awards prizes to machine's that can pass the Turing test.

The second motivating factor to the development of social robotics is perhaps an emotional one. Humans have the innate need for social dynamics however when humans interact in social dialogue there are often inhibitions that arise that do not allow completely truthful dialogue. We theorised that one of the greatest sources of these inhibitions is the fear of being judged by other humans who we engage with on a social level. We have always been fascinated by these types of social dynamics and the way in which we as humans shield our true selves in social situations to prevent other humans from judging us. However, after further research and pondering, We came to a remarkable conclusion. We concluded that what we might seek as humans is a sentient being that is not human but that is our friend. A being to confide in without the possibility of being judged but instead being understood absolutely. We theorised that it would be impossible for a human to confide in another human with the absolute impossibility of being judged. It is in human nature to judge, to form opinions on others, to take in and process information with an emotional response.

After coming to this conclusion We pondered further. One of the most problematic results of this conclusion was how We would possibly provide evidence of my conclusion without having to ask extremely personal questions to people. But then We came to the realisation that humans already form extremely close connections with non-human sentient species. Throughout recorded history, there have been stories and tales of the close connections some humans have with animals. So We sought out to find the most common human to non-human social connections We could find. Rather quickly we were confronted with the social connection humans form with dogs. The human-canine bond is one that dates back at least 15,000 years. This bond is often regarded as extremely strong and in some cases outweighs a human to human relationship. Dogs are often regarded as “man’s best friend” as they show extreme loyalty and love for their human owners. It is perhaps interesting to discuss the social dynamics of these human-canine bonds. It is recognised that in most human-canine bonds there is an unbalanced social hierarchy with the human regarded as the absolute dominant figure in these relationships. We contemplated whether it was this absolute dominance combined with the unconditional love of a sentient being that allowed us to form such close relationships with dogs. We also concluded that our social relationships with dogs are entirely different from our relationships with other humans. Perhaps if we were to continue this prototype we might seek to conduct our own studies on these human-canine bonds to fundamentally comprehend the nature of this common social dynamic.

We also recognised that there was required research into the components we would be using in our robot. These components would be critical to the success of our prototype and it was vital to understand the background of these components. The first component, we decided to research was MIRTO robot as our project was built upon it. We had to investigate how it has changed over the years and what has been added that we might use to our advantage. MIRTO is a robotic platform developed at Middlesex University with the help of students and staff. Department of Computer Science at Middlesex University decided to develop its own robotic platform to increase the effectiveness of their learning method. The MIRTO has been used in teaching since 2014. The students have the ability to write their own script which runs the robot. They can experience how the basics of programming behaviour of the robots look like and they can write it in different programming languages using such as Racket, JAVA, Python and Scratch. This robot supports all those four languages because the staff at Middlesex University wrote their own libraries. The students during classes are given a task, for instance, to make a robot drive forward or to follow the line, and after completing that task they are given a mark. The design of the robot has been developed in 2014 and some hardware component has changed. The design of the MIRTO board was improved. In the first version, on MIRTO board there was a motor driver circuit which was responsible for controlling the wheels. In the newer version of the robot, it has been removed and now, the HUB-ee wheels have that motor driver circuit built-in. Another, thing which was improved is the frame of the robot. The first iteration of the frame was much heavier as it contained metal elements. In the current version whole frame consists of the plastic, which improved the overall weight of the robot and, its maximum speed. When it comes to software, with the change of the design of the MIRTO board also pins which are mapped in the libraries have changed. After the research of this robotic platform, we understood that we need to research two of the most important components in MIRTO if they can handle OpenCV, TensorFlow and to execute our behaviours of the robot. We started the research of the Raspberry Pi 3. The concept of this single-board computer appeared in 2006, but in 2012 the first reports of the users surfaced about Raspberry PI. Over the years the performance of this circuit board has increased. With every new version of it, the new CPU was installed. Also, the first models had fewer ports. They increased the number of USB 2.0 ports from two to four. Moreover, they optimized the layout of the board. Next, the component we investigated was Teensy 3.2. With this microcontroller board, the history looked similar to the Raspberry Pi. Over the years, every aspect has been improved like performance and layout. For example, the first iteration had only 7 PWM capable pins and the most current version has 12. After that research of those components and robotic platform MIRTO, we came to the conclusion that we needed the most up to date hardware in order to maximize the performance of our robot. As it is crucial if our plan is to create a life-like device and it would not make an impression that this robot is alive if every task would be processed for a longer period of time.

Description of our prototype.

After our research had been conducted on social dynamics we had a direction of thought that we continued on. We sought to find the true definition of “Social”, it was to our surprise that the origin of the word social was Latin. The Latin word “socius” meant friend or friendship. It was at this point that we started to think of developing a social robot that might act as a friend. All the members of our group understood what the ultimate social robot would be. A robot that would pass the Turing test and be completely indistinguishable from a human.

However, we, unfortunately, did not have the time nor the resources to even attempt a robot of this complexity. Instead, we sought to develop perhaps the next best thing. A robot that represented a dog. Our long-term goal was to develop a robot that could possibly attempt to mimic a canine-human bond. The robot we have been able to produce should function as a prototype for the final product. Our prototype is made up of multiple sensors and motors to produce a great proof of concept. We have attached a camera to the front of our robot, we envision that eventually this camera would be integrated into the eyes of the dog. This camera currently serves as the main source of input for our prototype. We make use of artificial intelligence to detect faces and recognise the emotions displayed by those faces. Our robot is thus able to react to specific emotions it detects with incredible accuracy. In the current state of our prototype, the robot is able to detect happy and sad emotions on human faces. Once this emotion is detected our robot executes a series of commands that make our robot move. Our robot currently uses two servo motors with wheels attached to make it move. However, we envision a quadrupedal robotic dog as the final product. Developing a quadrupedal robot is notoriously hard and required extremely responsive and accurate servo motors to accomplish.

Hardware

After the research, we understood that our project was to develop a prototype, we decided to use a pre-constructed robotics platform to conduct our testing on. The pre-constructed robotics platform we used was the MIRTO from Middlesex University. Over the course of our degrees, we have all been in contact with the MIRTO in some form which made it perfect for us to use as the foundation of our project. Our robot consists of Teensy 3.2, Raspberry Pi 3, custom MIRTO board, 2 HUB-ee wheels and camera. Teensy 3.2, in our robot, is responsible for controlling two wheels and receiving over serial messages from the Raspberry Pi 3. It is a crucial element and to execute all those tasks, it needs a powerful chip. It is equipped with a 32-bit microcontroller with the core ARM Cortex. It has 64 KB of RAM and 256 KB of Flash memory. Moreover, it has 34 Input / Output pins and 12 of them are PWM channels. Also, 21 pins are analogue inputs. Teensy 3.2 is capable of tolerating voltages such as 3.3 and 5.0. That is due to that many legacy products still output 5.0V signals and new chips use 3.3V signals, but pins such as Reset, Program, AREF and analogue pins A10-A14 only use the 3.3V signal. Next crucial element is Raspberry Pi 3. In our robot is serves a role as the brain of the whole robot. It is responsible for human emotions recognition and sending specific commands to the Teensy 3.2. This board is a single board computer equipped with Quad Core 1.2GHz Broadcom BCM2837 64bit CPU, 1 GB of RAM, 40-pin extended GPIO, 4 USB 2.0 ports, HDMI port, CSI interface for connecting a camera, DSI interface for connecting a display, Micro SD slot for the card with operating system called Raspbian and Micro USB which serves as a power source input. The element which connects wheels and Teensy 3.2 is MIRTO board. It is a custom printed circuit board, developed at Middlesex University with the help of students and staff. It serves a role as a bridge between Teensy 3.2 microcontroller and other components. It has soldered on push button and potentiometer. Also, it has a switch button which is responsible for controlling the wheels. The pieces of hardware, which are responsible, for moving the robot are two HUB-ee wheels. These are universal wheels and can be in any other robot. It has a removable 12mm gear motor and the big advantage of these wheels is that is has a built-in open source PCB with Motor driver IC and 32 stripe quadrature encoders. Those wheels can be used with tyres or tank tracks. Moreover, it has two internal threaded inserts for mounting on to the chassis. The next element which is responsible for the robot's vision is a camera which is connected to the CSI interface on the Raspberry Pi 3. The model of the camera is Raspberry Pi Camera HD v2 8MPx. The device uses a Sony sensor IMX219 (documentation), has a matrix with a resolution of 8 Mpx, supports recording modes:

- 1080p / 30fps
- 720p / 60fps
- 640 x 480p / 90fps.

Raspberry Pi has hardware support for handling this camera, therefore the device does not consume CPU computing power. It does not require the installation of drivers for the operating system Raspbian.

Software

During the development of our prototype, we realised we would need powerful software to accomplish our goals. Our software would need to be able to detect human faces and also be able to detect the emotions recognised from those faces. This is not an easy task and this is made even harder with the limited processing power that is available on such a small robot. As we were using the Raspberry Pi we soon recognised the ability to use a python package named OpenCV. Due to my previous intrigue and experiences in real-time visual applications, I was aware of a suitable library for our project called OpenCV, which is an abbreviation of Open Source Computer Vision Library. OpenCV is an open source library that specialises in computer vision and machine learning. It is designed to provide a common infrastructure for software related to computer vision and machine perception[10]. Due to its incredible assortment of algorithms, it can simplify the production of video analysis software dramatically. In conjunction with OpenCV, we also made use of Keras. Keras allows for the use of artificial neural networks with relative ease in the Python programming language. On their website, they describe one of the main benefits of their framework: "Allows for easy and fast prototyping"[12]. Keras is a powerful library and can make use of multiple backends, we decided to make use of Tensorflow as it is incredibly popular and well documented[13][14]. On keras' website, they also state "Keras is an API designed for human beings, not machines. Keras follows best practices for reducing cognitive load: it offers consistent & simple APIs, it minimizes the number of user actions required for common use cases, and it provides clear and actionable feedback upon user error."[14] Therefore we found that this framework would allow us to build a simple sequential neural network to test our data against real training data. By using keras we were quickly able to set up a neural network with our limited research and knowledge of neural networks.

We then proceeded to train our neural network against a pre-existing dataset with approximately 30,000 facial expressions with their corresponding label. Our neural network was then trained on a PC with powerful hardware. This allowed our neural network to be trained in approximately one hour. This is one of the major advantages to using neural networks. If we were to use standard mathematical algebraic equations it would not be realistic to expect every frame to be analysed in real time thus making our robot useless. With the advent of neural networks however we are able to train a model which will have set weights for each neuron. Once we have these weights set the analysis of the input data is extremely efficient this allows us to analyse each frame in real time even on limited hardware such as the Raspberry Pi.

Once our model was trained we used a Python script that included our trained model. This python script would then analyse every frame from the camera. If a face was detected and the estimated percentage certainty was above our threshold of 80% a command was sent to the teensy with information regarding what emotion was detected. That information would be processed by the script written in Arduino IDE which was uploaded on the Teensy 3.2. In that script, the message is filtered by the IF statements in the loop function. Then the script would check if the robot is not executing any behaviour. If the robot was free, the function called "SetMotor" would be executed and as a variable, the message would be passed as an array. In that array there is a duration how long the wheels should be running and a number which indicates what behavior the robot should start. If the value equals 5, the robot will execute a function called "SetHappy". Also, if the value equals 6, the robot will execute a function called "SetSad". The function "SetHappy" sets the launches the behaviour which imitates happiness and "SetSad" launches a behaviour which imitates a sadness. Those two functions are a set of commands such as "analogWrite" and "digitalWrite" and during the execution of those functions, a boolean variable called "isBusy" is set to true, and at the end, this variable is set to false. This indicates whether the robot is executing the behaviour, and it does not start another until the first one was finished. This is a measure to make sure that all the behaviours are correctly executed. At the begging of the script the pin modes are set, and serial communication is started to receive messages.

Testing and evaluation

For our robot is was extremely important that we conducted proper testing which would allow us to evaluate our prototype properly. To conduct proper testing we first wanted to state the expectations we had in mind for our prototype. Once we had established our behavioural expectations we would then be able to compare these to our test results. Our expectations were as followed: when the robot has not detected a face or emotion it is stationary. If the robot detects a face but does not perceive an emotion to be present it will remain stationary. If the robot observes a sad face and the neural network is over 80% certain that it has detected a sad emotional expression then our robot executes a preprogrammed behavioural script that is specific to the sad emotion. If our robot detects a face and the neural network is over 80%

certain that the happy expression has been detected the robot executes preprogrammed behavioural script that is specific to the happy emotion. We ran a total of 20 tests with 10 of the tests being a happy emotion and 10 being a sad emotion. We had a total of 5 members participating in the tests. Each member would act out 2 sad reactions and 2 happy reactions.

Our test evaluations concluded that every single test was a success meaning the robot was able to detect the correct emotion and execute the specific preprogrammed scripts in good reaction times. In most of the tests, the subject would only need to display the emotion for a second before the robot would react to the subject. What we did notice however is that the robot would only perceive intense emotional expressions. This meant that the subjects would need to display extremely sad or happy faces to make the robot react. We believe this is due to the dataset containing a large amount of extreme emotional expressions. Meaning our neural network has only been trained to recognise extreme emotional expressions rather than subtle ones. Besides this, our robot behaved exactly how we predicted and thus our evaluation was successful.

Conclusion

To conclude this report we will discuss our projects evaluation and future possibilities. What we have accomplished is a great proof of concept for future development. We believe that we will see animated toys that will be able to mimic the behaviours of household pets. We have been able to accomplish what we set out to achieve. Towards the end of the development of our prototype, we also discussed the possible future implementation of this type of technology. An interesting proposition that was brought up was how easy it might be to implement this technology with pre-existing quadrupedal robotic platforms. One such platform was produced by Boston Dynamic as you can see in figure 2. This robot has been developed to function as a platform for further development.

Figure 2. Boston Dynamics quadrupedal robot.

There were stages during the development which complicated the development of our prototype. One such complication was when we attempted to run our neural network on our Raspberry Pi. It was incredibly hard to install OpenCV on the raspberry pi and this stage of the development took incredibly long. For all of us involved this was our first project where we combined the development of both hardware and software into one prototype. Although this was a challenging project we feel we have gained a large amount of experience from this development.

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