Development of Brando: a robotic dog capable of expressing emotions

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Abstract

Robotics is a field that continues to grow and expand, and its presence is mostly found in the industry. Nevertheless, robots are joining our daily lives in many ways. An exploration of social robots was done after building Brando, a robotic dog able to express emotion with the use of a robotic tail and ears. A study was built and developed where subjects were divided into different groups, and each group saw the robot with different characteristics. After it, each one answered a survey. This questionnaire was constructed to see which perception of Brando they got and if they were able to build an emotional connection with the robot. It was found that movement in the ears and tail of the robot was directly linked to a positive impression of Brando and higher levels of empathy.

1. Introduction

Technological development in the field of robotics is experiencing accelerated growth in the areas where it is applied. However, research related to its social and emotional impact, hand in hand with its design and characteristics, makes up a little-explored area.

The analysis of the social impact of robots and the way in which design and characteristics influence a dynamic of coexistence and acceptance within a society that is increasingly in contact with technology becomes essential for the comprehensive development of robotic projects with the intention to assisting vulnerable social groups.

The concept of quadruped robots has been around among robotics field enthusiasts for a while. However, most developments have been strictly focused on opposite industries. One example is Sony AIBO, a robotic dog-directed towards the toy industry, capable of interacting with users through a set of cameras and sensors, developing a personality over time through daily interactions.

A study on the impact of AIBO made by [1] gathered information about the interactions of 72 children between the ages of 7 to 15 years old with Sony's robot and a live Australian Shepherd dog, showing a close resemblance in perception and behavior towards the live dog and the robot. Subjects encountered concepts related to living dogs, such as the robot having physical essence, mental states, socially, and moral standing. Thus, subjects interacted with AIBO in similar ways as they did with the live Australian Shepard, and they appeared to be more willing to interact with the robot rather than with the live dog closely.

Probably the most prominent example of a development of a quadruped robot directed towards the industry is Spot from Boston Dynamics, a robot widely used in construction sites, nuclear energy plants, and even in rescue tasks, as its form factor allows it to take part in activities that take place in very limited space scenarios .

In a study developed by [2] to target the challenges and automation of data capturing during construction processes, an automated on-site 360° image capture module was added to Spot, and a series of weekly experiments took place at the site, monitoring construction processes to obtain factors and indicators related to the economic impact and overall, organizational performance within construction projects.

In research related to the overall development of walking robots, [3] created AQUA, a robot capable of walking underwater with a combination of a relatively simple hardware design and sensors along with a software design created to test the capabilities of a mapping navigation system technology in shallow-water environments.

Studies keep on highlighting the limited research on factors directly attached to a robot's appearance and emotional showing capabilities, with the impact that these two have when a robot is not directed to a specific sector or industry and it is also not limited to work as a toy for entertainment.

This paper presents the development of a quadruped robot with no specific target industry at this point and the findings behind an interaction study to gain an insight into the relevance of emotional expression and appearance on human-robot interaction.

After building the robot, it was decided to use it as a tool to further investigate the main characteristics that a social robot should have to promote its acceptance. Exploration of human-robot interaction has been done before but in most cases, with an industrial approach. Within this type of research, it is possible to find information to better understand how humans perceive robots. For example, [4] concluded that speed was an important factor that influenced subjects' opinions of robots. As it was mentioned that feelings of discomfort decreased only when the speed matched subjects' expectations.

When it comes to analyzing emotional connection with robots, different types of studies have been done using commercial robots. An example is a work done by [5], using Sony AIBO, pointing out that adults need a longer first impression contact to establish an emotional attachment to AIBO than children. Also, functionalities are important as the interaction of adults with AIBO was more functional-oriented or device-related.

Empathy towards robots has been observed in various studies where people were asked to inflict some type of "harm" to the machine to see if they felt comfortable doing this. For example [6] conducted a study in which subjects were asked to trigger electric shocks to an anthropomorphic robot capable of expressing emotion on its face, shaking its arms, and using a speaker. It was found that subjects did feel compassion for the robot. Nevertheless, little encouragement was enough to lead them to continue with the experiment. Concluding that people have fewer concerns about abusing robots compared to abusing other humans.

Next [7] has published research on how communication impacts people in different scenarios and how communication plays a vital role in the influence of physical and mental health. [8] have written about the strategies through which introverts can communicate to improve their careers. Therefore, it was proposed to add the capability to communicate using sign language with the robot setting different signs as commands, such as sit, stand, come, go, etc. Trained on top of a machine learning module that helps people suffering from mental health conditions and introverted people who don't feel comfortable communicating verbally.

2. Development

For the research on this matter, the design of a robot capable of demonstrating emotions in a similar way to a real dog and studying its social impact and interaction within a specific population sample was purposed. Brando, the robotic dog, was assembled into three main parts defined as: the head, the torso, and the legs.

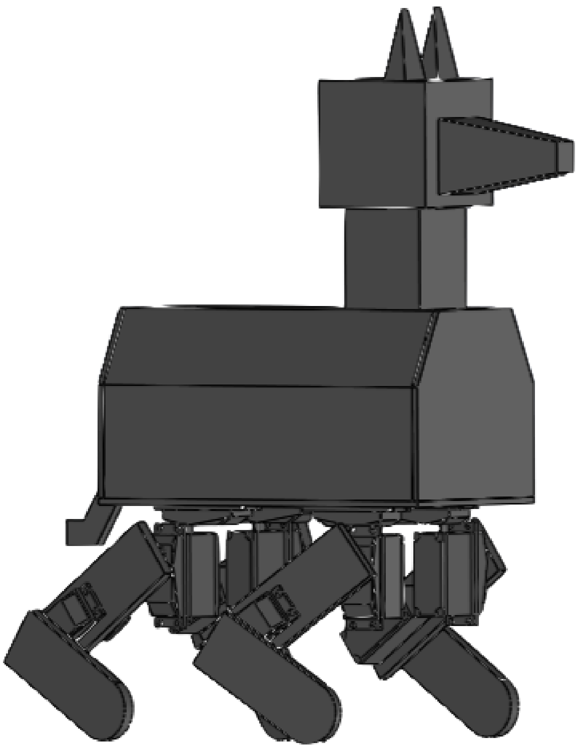


Figure 1: Brando Design.

2.1. Brando's Design

The head of the robot was designed to have a close similarity to the head of a medium size dog.Therefore, it includes the design attributes that contribute to the expression of emotions, such as the moving ears, a set of eyes, and a microphone that resembles a dog nose.

The torso area was set to contain the power and control elements, such as an 8000 mhA LiPo battery used to power up all the moving components and the logical processing system, a Raspberry Pi 4 Model B that uses Python to control the movement of all the components in Brando besides retrieving data from its sensors.

The main motion system, defined as the robot's legs, is built up of two wood pieces attached to the robot's torso. On each moving part of each leg, a 60 kg/cm torque servo motor is placed to provide movement, giving Brando a total of 3 degrees of movement. These pieces are all joined together by an Axial 32 mm 51106 metal bearing to provide a more stable movement. It was seen in earlier development stages that the servo motor joint had little to no stability at all when taking part in challenging movements.

On the previous development of four legged robots, an article was found made by [9] where a walking system was developed and tested based on walking dynamics to understand the mechanical limits of the design when the robot moved with trot gait, founding a similar appliance with our design attached to the placement of moving mechanisms on top of the four legged structure, this information was used to find the limits to which legs can be set to provide a stable movement for this type of robot design.

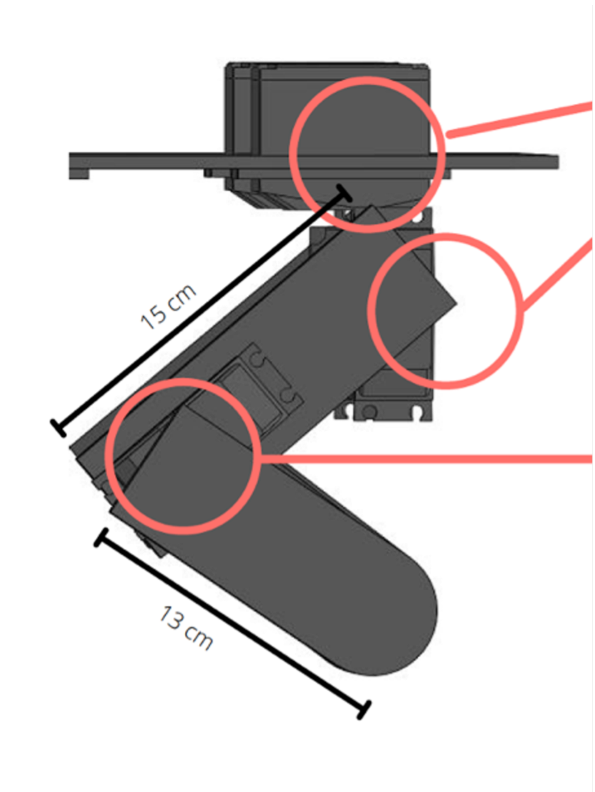


Figure 2: Brando's Leg.

To provide the robot with the ability to show emotions, it was decided to replicate two basic characteristics that dogs use to show their emotions, according to different studies: the tail and the ears.

For each attribute, a mechanical system was designed with an appropriate range of movement to be able to imitate the movements carried out by dogs when expressing 5 of the 6 basic emotions proposed by [10]; Happiness, Sadness, Anger, Fear and Surprise.

For the mechanical design of the tail, we used research done at the University of Manitoba by [11]. In this study, a robotic dog tail prototype was built and attached to a vacuum robot with the purpose of mimicking tail emotional expression and validating its accuracy by asking participants to rate each motion in terms of perceived robotic affect. The tail's horizontal and vertical movement was achieved by using two servo motors and a flexible tail with a cable-pulley mechanism.

The tail mechanism was composed of two 35 kg/cm torque servo motors with a circular wood piece attached to the motor gear, and each piece had two cables attached to opposite points of the circular perimeter. The tail is made up of 7 plastic dice joined by a spring in the middle. Each dice has 4 visible faces with a metal hook having enough space for the cable coming from the motor's moving piece to pass through it. In the last dice of the tail, the 4 cables are unified to provide stability and transfer the motors' movement to the dice.

The first motor is responsible for the horizontal movement of the tail and the second motor is responsible for the vertical movement. These two movements allow imitating a dog's natural movement. The mechanism is mounted on a wooden base that integrates its components as well as adds stability to itself, applying changes in cable tension to generate movement.

Two 35 kg/cm torque servo motors were used to build the ears, each with a metal piece and a cable attached to the edge of the piece. The second cable end was attached to the top of a system made of two wooden parts held together by a spring. By moving the motor, the cable transfers the movement from one element to another, thus, imitating the movement of a real dog's ear. This mechanism was mounted on the external head structure that simulates the head of a real dog.

2.2. Brando's Interaction Study

To be able to identify the key elements that a robot must have to promote a positive response towards it, a study using Brando was implemented.The main purpose was to point out to which extent the emotional expression (movement of tail and ears), appearance (wood or fur), and speed (fast or slow) of the robot would influence the subjects' opinions. With the use of these three variables, the population was divided into 8 different groups.

Groups were divided evenly taking into consideration equal distribution between male and female subjects, their ages, and if they are dog owners or not. Due to COVID- 19 restrictions, the study was conducted virtually. A video of Brando performing a task was shown, followed by a survey. This was done several times in a 6 months lapsus to assess their reactions, opinions, and interactions, as well as the evolution of the results over time.

For the development of the survey, the Robotic Social Attribute Scale (RoSAS) was used to make sure Brando's perception was accurately measured . RoSAS focuses on three scale dimensions: warmth, competence, and discomfort [12].

When building the experiment, different research was analyzed related to how humans interact and establish emotional bonding with real dogs, as our dog resembles a medium-sized dog.

Some findings in recent studies on why humans turn to the company of a dog have concluded that the main motivations for seeking any type of dog bonding are related to the basic human need for company. For example, dog's role in a family network is more likely to evolve into a

Figure 3: Brando's Wood Appearance

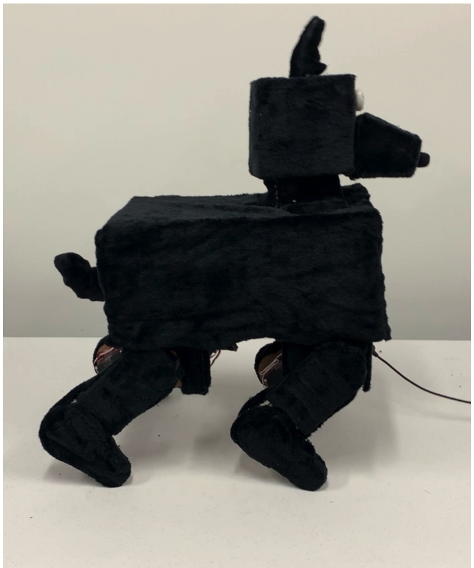


Figure 4: Brando's Fur Appearance

human-like social interaction dynamic between dogs and its owner [13]. Therefore, we expected that the prototype's resemblance to a living dog and the use of moving attributes would make subjects feel attracted to interact with it similarly to a live dog.

After this study was completed, shortened versions of it were conducted, with a reduced number of groups. The most recent one was done at Sungkyunkwan University, in South Korea. For this study, the population was divided into two groups, both watching a version of Brando with fur, the main difference being the movement of the ears and tail, turned ON or OFF. Some of the most outstanding results were found in the following questions.

For the following images answer options are represented as it follows

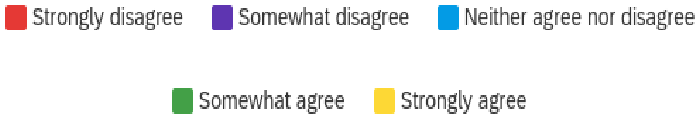
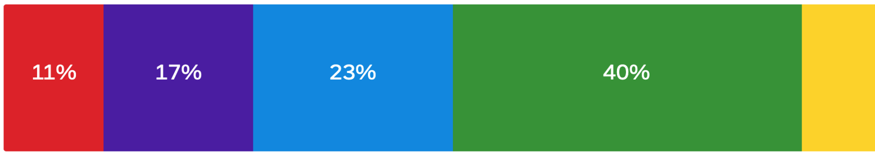
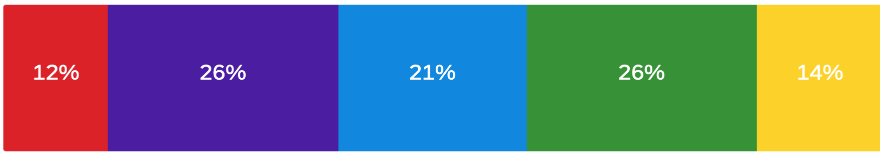


Figure 5: Options for Survey.



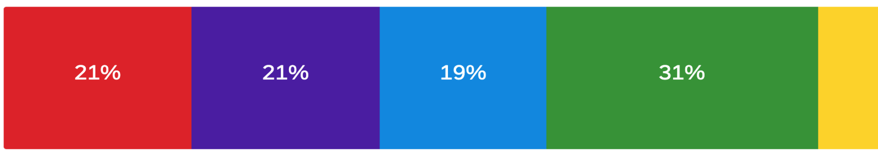
Group 1 (Fur and emotional expression ON).



Group 2 (Fur and emotional expression OFF.)

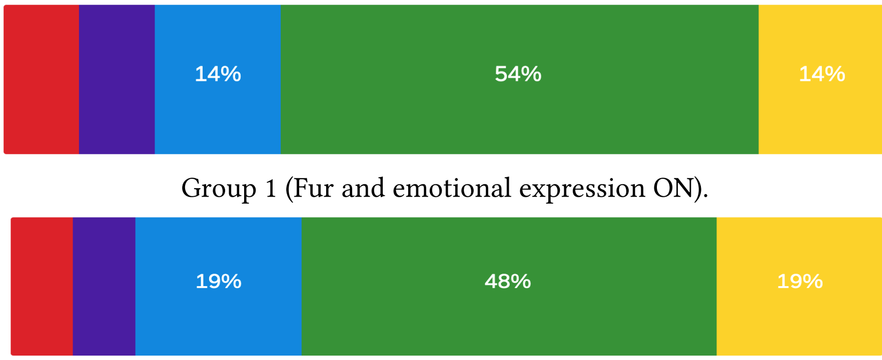
Figure 6: Q1: Brando looks like a dog.

Group 1 (Fur and emotional expression ON)



Group 2 (Fur and emotional expression OFF)

Figure 7: Q2: The tail and ears help Brando express how he feels.



Group 1 (Fur and emotional expression ON).

Group 2 (Fur and emotional expression OFF)

Figure 8: Q3: I would feel bad if something happened to Brando.

Overall, it was concluded that the movement of the tail and ears has an important positive impact on the way subjects perceive Brando, which was consistent with the other studies done before. When it comes to empathy, results were very similar for both groups. This was expected as in studies where different appearances of the robot were shown, it was identified that the variable that affected empathy was the appearance of Brando. As subjects expressed empathy with both versions of the robot, but with greater intensity when the fur version was shown. Figure 8 is the flowchart of the Machine Learning model and it's described in the below subsections.

2.3. Data Collection :

50 videos from different races of people performing sign language were collected, these videos were then converted into images, resulting in about 150 pictures for each sign. Later, these images were augmented with the help of Imgau [14] library, and the data augmentation techniques used were Gaussian noise, salt and pepper, and flipping. The reason for choosing only these augmentation techniques was that it was seen from [15] as the effects of salt and pepper were specified, which had a considerable image impact on the image. Resulting in the formation of a new image when it comes to Gaussian noise [16] describes how adding the Gaussian noise improved the robustness of the model without compromising accuracy. [17] published a survey on how data augmentation increases the accuracy of the machine learning model and also shows the advantage of using flipping as one of the augmentation techniques.

2.4. Object Detection:

Two different object detection models were tested suitable for the Rasberry-pi, Tensorflow based single-shot detector mobilenet [18], and an improved YOLO based YOLOV3-tiny model [19]. Still, it was observed that Tensorflow based machine learning model performs better than the YOLO-based machine learning model. [20] also shared the results where a huge difference in terms of accuracy when the user has the distance with the camera was identified.

2.5. Brando and Google-vision Kit :

Google-vision kit is placed on the top of Brando's head through which the object detection is performed.

Google-vision kit is built on top of Rasberry-pi support's image classification and object detection. Still, there are certain drawbacks in the image classification where the machine learning model will not be able to recognize if multiple different objects are shown. Hence, we chose to go with the object detection model.

2.6. Brando Obeying the Hand-sign

Once the sign is detected with the help of Google vision kit, a string value will be obtained from it corresponding to the specific command or routine that wants to be triggered. This data will be used as an input in the main program of the robot to run the sires of movements that correspond to it.

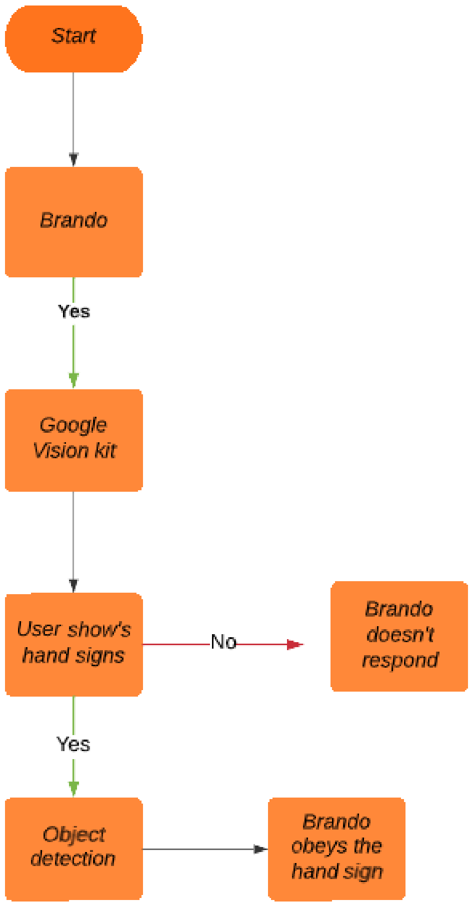


Figure 9: Architecture.

3. Future Works

In the next stages of this project, various improvements will be done. They are beginning with a change and adaption of the me- chanical design of the robot to make it lighter and as a consequence, achieving a better movement. For this purpose, the next approach will be 3D printing a new body for Brando.

Once Brando's walking is improved, more complex applications for the robot will be explored with the addition of sensors for autonomous movement and a camera for object and person recognition. This way information from the environment can be used to control Brando's emotions and actions to interact with people around him and become a useful companion. Including different ways of interacting with the robot to make it accessible to most populations.

Specific applications like setting Brando as a companion for disabled people, people who experience anxiety, people who suffer from cynophobia, people with allergies or for the elderly will be explored.

When the capabilities of the robot are expanded and COVID-19 restrictions continue to become more flexible, a set of different studies would be done, looking to get a deeper insight into human-robot interaction with a quadruped robot able to express emotions.

After analyzing the retrieved data, a bias was encountered, leaning towards a major level of acceptance, interest, and understanding of four-legged robots, since most of the subjects belonged to a computer science program and were part of a group between the ages of 18 to 25.

Despite having a wide variety of nationalities within the subjects in our focus group, a necessity for a deeper understanding of its cultural impact was highlighted. By creating another study with a larger and a more representative diversity group, it is expected to get a better view on how cultural differences impact interactions with robots.

4. Conclusions

It was concluded that adding emotional expression to Brando had a great positive impact on the way people perceive the robot. This leads to understanding the importance of elements such as the tail and ears for reducing feelings of discomfort when interacting with Brando. After the design and development of Brando were completed, it was brought to attention that a change of material would improve its performance considerably. As budget and machinery are limited, it is understood that continuing with this research will take time. Nevertheless, efforts will be done to continue with this project and use the information gathered in the studies to lead to a better design of Brando and achieve higher levels of acceptance when applied in social situations.

5. Acknowledgement

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6. Links

For further references visit https://youtu.be/Tg_5qGd2-ME and https://youtu.be/mq3_U-Nj7Es

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