Developing an Robotic Rover Capable of Acting as a Surrogate for an Emotionally Responsive Service Dog

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***Abstract*—Emotional support animals have become integral to modern society. They find themselves in all walks of life, as mental health takes its toll on many. However, there are many places where animals are not allowed or wanted. As such, there is a need for the development of robots that are capable of filling the place of these emotional support animals. This project discusses the benefits and drawbacks of implementing robots into the role of emotional support animals, and delves into the methods and results of such implementations. This report also discusses other use cases for this technology, to see if robots can be used in place of animals in other roles. A combination of pathfinding, face detection, and facial emotion analysis was utilized to form a robot intelligence that would be able to fulfill the role of an emotional support animal. The robot can identify its owner, see how they're feeling, and react accordingly. The contained report describes both the hardware and software used in this project, and discusses improvements that can be made to the robot to engender greater performance. This work suggests that efforts to implement emotional support into robots are well-founded and that robots have a place in the role of emotional support animals. Additionally, this work discusses the various applications that this sort of robotics implementation can be worked into, including other roles animals play in society.**

***Index Terms*—Artificial intelligence, emotion recognition, facial recognition, Python, robotics, service animals**

I. Introduction

The topic of robotic service animals is a wide and diverse discipline of research intersecting many areas of interest. There are so many overlapping areas of focus that it can be difficult to clearly delineate between the various sub-disciplines counted in robotic service animals. For the purposes of this paper, the scope of this review is restricted to those sub-disciplines which pertain most strongly to the development of this project. Specifically, the sub-fields of *Therapy Robots, Recreational Robots*, and *Emergency/Disability Service Robot.*

a) Therapy Robots: Due to advancing research into the field of physiology, there has been increasing institutional adoption and cultural acceptance of therapy. In turn, this has resulted in an increasing demand for said therapeutic services, especially in traditionally minimized low-impact and/or long-term applications. Many have looked to robots to help fulfill this emerging need. Many hospitals and care centers have seen success in using robots to satisfy these needs, both in cases of children [1] and in the elderly [2] [3]. While healthcare fields have seen the potential of robots to provide emotional care to their patients, they are not the only ones who have taken interest.

b) Recreational Robots: While still a burgeoning field, the market potential for domestic robots is growing, with likewise growing interests in the ramification of such. Artificial Intelligence engineers have begun looking for what effects they can achieve by reading user emotion. Initial research shows that robots can influence the emotions of their users by responding to said emotions, much like with human interaction [4]. In particular, toy manufacturers and those specializing in childhood development believe that the powerful potential for human bonding could be leveraged in making highly popular recreational robots [5] [6].

c) Emergency/Disability Service Robots: Differentiating itself from the above fields, this field of robotics is concerned much more with function rather than form, focusing on designs capable of completing an objective, such as locating an individual, navigating a person through an environment, or assisting some with a disability [7]. While aesthetically very distinct, this sub-discipline shares many of the same technologies and integration strategies as the prior two.

It is under this umbrella of projects where government contracts, and coincidentally, the most steady development of support technologies, such as facial recognition [8], human interactivity [9], and modality [10] are found.

II. Related work and Background

How should robots be designed to benefit humans? Intelligent machines with empathy for humans are sure to make the world a better place. Animal robots are designed to look, move and sound like an animal, and they may be used to interact with people in a socio-emotional way. When designing an emotional support animal robot, it is important to be able to recognize human emotions. Emotion evaluation methods can be classified into two main groups according to the basic techniques used for emotion recognition: self-report techniques

[11], and machine assessment [12]. A number of studies with the robotic dog AIBO have already been conducted. The interactions between kids and AIBO and how they view the robotic dog are a major subject of many of these investigations. The majority of studies [13] [14] focused on how the robotic dog differed from real dogs or even toy animals. Despite the fact that there were variations in how the kids interacted behaviorally, they discovered commonalities in the way the kids reasoned about the robot and the plush dog. Robotic animals can replicate human emotions and engage people in intimate interactions. Reeves and Nass [15] have demonstrated that humans interact socially with technological artifacts like computers, and as such it stands to reason that socially built robots will amplify this effect. The emotional engagement of robotic dogs has also been studied in therapeutic settings. For instance, Marti et al. [16] investigated the therapeutic potential of the seal robot Paro; their first findings revealed a clear function for the robot in mediating social exchange and promoting attachment and engagement.

In some studies, there have been research about biology-inspired assistive robotics which refer to service dogs as a model for human-robot interaction and mobile manipulation. [17] Thousands of people with motor impairments have benefited from service dogs worldwide. A biologically inspired robot that can follow many of the same commands as service dogs and take advantage of the same contextual adaptations as them is proposed as a first step toward the development of robots that offer help on par with that provided by service dogs.

Here in this work we will focus on bridging the gap between living and robotic pets by proving that robots can be designed to emulate some of the many characteristics that make current support animals so endearing.

III. Methods

Due to the limited development time and personnel resources, many of the desired features discussed in the background session had to be reduced in priority, or removed entirely. These features include, but are not limited to, using a legged platform, touch based feedback, non-audio emotive action, and game-playing behavior. While such additions are arguably necessary for a commercially viable product, this research focuses on developing a baseline for future development. The key features of this development are as follows: First, object detection and collision avoidance; second, owner identification; third, emotional recognition and response.

The platform used for this work is based on the Raspberry Pi 4 computer with 4 gigabytes of RAM. We used the 64-bit version of Raspberry Pi OS for our development. The programming language Python was selected for this work, as it has many available libraries for handling the objectives that we had in mind.

A. Object Detection and Collision Avoidance

The concept behind this objective was to make the service animal robot more realistic. As such, it was designed with the ability to roam around freely. This feature required that the robot be capable of navigating in its environment.

The hardware used for this work, shown in Fig. 1, came with some sample code already written, which takes advantage of the Raspberry Pi core GPIO library. Using this sample code, we were able to use the onboard sonar and infrared sensors to detect nearby objects. The rover has a single sonar sensor in the front. This sensor is capable of detecting the distance of objects, and has a moderate range of a few meters. The two infrared sensors face diagonally off the front corners.

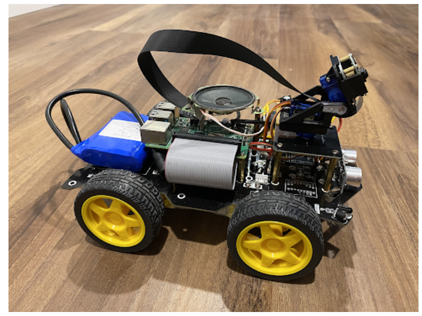

Fig. 1. Rover platform used for development.

02 The algorithm developed for roaming was kept rather simple. The rover continues forward unless obstructions are detected. If there is an object detected in front of the rover, it will turn sharply 90° to the right, then proceed. If there is an object detected to one side or the other, then the rover will slow the wheels on the opposing side, until the object is no longer detected. By doing this, the rover is able to wander freely, without human interference. One additional feature, which is outside the scope of this work, would be the addition of a randomization factor. This would allow the rover to arbitrarily select a new direction on its own, regardless of objects having been detected.

B. Owner Identification

In order to implement this objective, we used the Python *face_recognition* library, which can be installed through pip. This library is initialized using an image of the person we want to set as the owner. This library can also take multiple images, as shown in Fig. 2.

We realized early on that this process, as well as the process that does the emotion detection, were going to be the bottlenecks of the system. We decided that the best approach would be to run these processes on separate computing threads. In doing so, we designated the main thread as the only thread which had control over the GPIO. This way there could not be conflicts between threads over controlling the servo and motors. We also wanted to keep the main thread operating quickly, as it would be in control of the object detection and collision avoidance.

While threading the slower tasks worked to free up the main thread, we still had to communicate information between each thread. In order to accomplish this, we created flags and buffers, which could only be set or written to by their

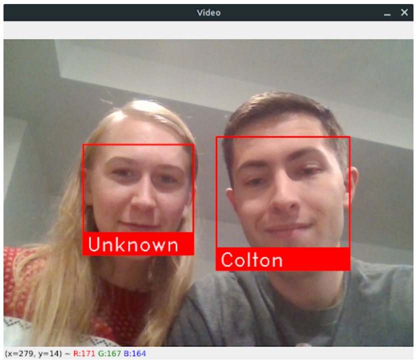

Fig. 2. Facial Identification from the robot's perspective.

designated thread, then cleared or read by the main thread. The main thread would then exercise the main decision making logic, for how the rover would respond to its environment.

C. Emotional Recognition and Response

In order to implement this objective, we used the Python *fer* library, which can also be installed through pip. This library uses an artificial intelligence network for recognizing human emotions. This library is also capable of classifying multiple subjects at a time, as shown in Fig. 3.

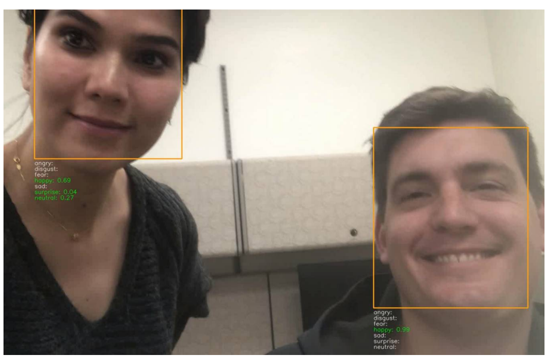

Fig. 3. Emotion classification from the robot's perspective.

The emotion recognition process took the longest amount of time by far. If the rover recognizes a subject, the current frame is then handed to a new instance of the image recognition thread. Based on the dominant emotion detected, a corresponding sound responses is queued. Within the main thread, the sounds are dequeued and played over the rover's onboard speaker. The emotions and responses are shown Table I. The X indicates that the emotion does not matter.

Is Owner	Emotion	Response
No	X	Growl
Yes	Happy	Bark
Yes	Sad	Whimper

TABLE I
DOMINANT EMOTION AND CORRESPONDING RESPONSE

IV. Results

For the final results, most of the objectives were successfully completed and fully functional. The real issue we faced was that of integration. All of the processes worked individually, though when combined, errors would arise. These errors did not always manifest however, and seemed to stem from some underlying issues with the dependencies related to the libraries we used. For the most part though, everything worked as designed, and our objectives were archived.

Included here is an external link to a video demonstrating the robot acting in a domestic environment: DemoRobot.mp4. At the beginning of the video, one can see the robot successful avoiding the various obstacles in the environment, including the small profiles of the table feet. As one of the programmed "owners" steps into frame, the robot pauses while evaluating the face, then begins following once there ID has been verified. Once a new person replaced the previous "owner", the robot once again pauses to evaluate the new face. After several attempted identifications where returned as "Unknown", the robot turns around and fees the stranger.

Unfortunate, due to the limited processing power of the robot, requesting a live feed began bottle necking the onboard Raspberry Pi, thus causing latency and lag though the run. However, despite these performance issues, the robot was still able to successfully demonstrate all of the core behavior routines this team implemented. Once can see both the Facial emotions and IDs being read off of the users, the behavioral decision tree responses, and the generic obstacle avoidance all being successful executed.

V. Discussion & Conclusion

In this project, we successfully accomplished the goals we set for this robot. It is able to identify an owner, react to its perceived emotional state, and wander its environment when it can't see its owner. While this is far too simple to properly fulfill the role of an emotional support animal, it is an excellent framework to get started on. Future improvements will likely be iterative, as not much will need to be built from the ground up when additions are made.

A. Method Improvements

While our implementation of an emotional support robot fulfilled all of the goals we set out to accomplish, there are plenty of improvements to be made that were simply out of the scope of this project. Typically, an emotional support animal is a legged animal. To make the required computation for locomotion easier, we decided to design our robot to be a wheeled robot, using a typical skid-steer model. The change to legs is something we would like to add in the future to better emulate emotional support animals. We would also like to add other ways for the owner to interact with the robot and vice versa. For example, we would like to add touch-based feedback. A robot that could be touched to be interacted with would feel much more organic for its owner. Other things we would like to add in the future would be the ability for the robot to do tricks and play games, as well as have non-audio emotional responses to its owner. All of these improvements are means to the end of making an organic experience with a robot that can emulate the experience of having an emotional support animal.

B. Future Developments

The potential of this implementation of robotics extends far beyond the scope of just emotional support animals. Animals are used in all sorts of roles in society. For example, with only some small changes to the software, the robot from this project could be used as a seeing eye robot, filling the role of a seeing-eye dog. Robots with better traversal mechanisms could be used as emergency response animals, finding people who are lost in the wilderness or finding and identifying hurt or injured people. There is a lot of potential for robots with the capability to respond to emotional inputs. These robots can and should be considered for integration into society, and will likely be a great help to society as well.

C. Conclusion

To conclude, there are lots of applications for the research and implementations of robotics described in this work. Emotion and facial recognition can be well utilized onto low-power robots, which can be used to interact with humans to better their living experience. The application we covered was emotional support, and we were successfully able to develop a robot that can locate its owner, identify its current emotional state, and react to that state. This implementation of robotics and artificial intelligence can be applied to several other applications, including full-on therapy robots, robots used for recreation, and emergency and service robots. As these sorts of robots are developed, they tend to become a lot more expensive, as more powerful hardware and software is required to provide better performance. However, these advanced applications of robotics have a huge potential to not only further the research of robotics, but provide many services via robots where animals may not be the preferred choice.

VI. Contributions

Jonah Boe

Implemented obstacle detection, collision avoidance, audio response, and the initial emotional recognition.

Colton Hill

Debugging, facial recognition, code integration, testing, demos, presentation.

Tyler Conley

SSH Connection, Linux setup, code verification

Kobra Bohlourihajar

Documentation, code review, assignment requirement compliance, Direct lab liaison.

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