An Expressive Layer for Mobile Robots

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***Abstract*— In viewing and interacting with robots, users attribute character traits to the system. This attribution often occurs by coincidence as a result of past experiences, and not by intentional design. For example, many Roomba users have posted videos to the Internet making fun of their behavior. Attribution through the means of a design elements can serve as a valuable tool to change user perception. This paper presents a flexible, expressive prototype that has been designed to implement a methodology for creating intentional attribution to mobile robots, resulting in an altered perception of the non-anthropomorphic robotic system. The prototype allows customization through five modalities: customizable eyes, a simulated breath motion, movement, color, and form. This design allows for rapid character prototyping and could enable user customization, which could prove to be especially useful in the case of special populations such as older adults, who are more hesitant in adopting new technologies.**

I. Introduction

Robots hold the potential to help in home scenarios, particularly inside the growing market of older adults. An increasing number of consumer robotic systems are being designed for the household environment, e.g., commercial assistive robots like Bosch's Mykie robot, Mayfield Robotics' Kuri, Jibo Inc.'s Jibo and Anki's Cozmo. The success of these already functional robots is largely rooted in their acceptance by users. This acceptance is owed to multiple factors such as lifetime experiences, predictability of behavior, perceived ease of use, and hedonic value [1].

Another key factor is the concept of psychological attribution, whereby a user's opinion on technology is altered by their perception of physical characteristics of a piece of technology, as well as the rhetoric surrounding the technology itself. Even when this attribution is not attended to by robot designers, users will create narratives that explain the animations of robotic devices.

Prior work [3], [4] shows that it is natural for humans to try and extract information from robotic actions, subsequently attributing intentionality to robot movement characteristics. In [2] user study participants describe the movements of a robot vacuum cleaning system, the Roomba as "cute" or "pathetic", even though such a correlation may not have been intentioned when designing the purely functional movements of a Roomba. Further, in this study, users named their Roomba robot, giving it an added social identity. The achievement of social assimilation albeit by coincidence and not by intention is an example of users associating decisions made by the robot to its personality traits, as opposed to the functional algorithm that determines its movements.

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Individual perception of technology develops over a lifetime of experience and can have unexpected contributing factors. This can result in an individual perception based on consumption of different forms of media and storytelling. Priming is a psychological tool that can be used to tap into this perception through an intentionally designed rhetoric that can be attached to different forms of technology. The work in [5], explores the relationship between emphatic concern and the effect of priming through stories in the interaction with robotic systems. Two groups of users are asked to strike a robot insect with a mallet; results of the study show that people are less likely to strike the insects with a backstory.

II. Prior Design Methodology

In prior work we have developed a robot design methodology to project character archetypes onto robotic systems of different form factors [6]. This work adapts product design methodologies, the Kansei Engineering iterative design approach [8] and the Product Channel Consumer paradigm [7], to include considerations of how a product should *move*, leveraging elements of Laban Movement Analysis [9].

In [6], we used this methodology to abstract known, archetypal characters onto virtual robots in 3D environments. This included a user study in Virtual Reality where users were able to successfully identify robotic characters. Following this, we wanted to explore more subtle, customizable characters with less exaggerated personality types, with the goal of increasing the predictability and familiarity of the hardware without inciting a lifetime of bias.

III. Fabrication, Assembly, and Control

The design methodology outlined above was used to develop a prototype through the implementation choices described here. We use the iRobot Create 2.0 mobile platform as the form factor for the dancing droid (DD) prototype to augment. This unit is cost effective, easy to work with, and shares the base design as one of the most popular and prevalent in-home robots, the iRobot Roomba. The DD is comprised of four modular components, easing the process of assembly. These four components, the shell, the core, the eyes, and the expressive lights, are delineated below with explanations of the fabrication and assembly process.

A. Shell

The shell encloses the electronic components and gives the DD its intended shape. In order to keep the mass as low as possible, the shell is created by stacking sheets of Expanded PolyStyrene Foam (EPS), along with a hemispherical top. The EPS foam is cut to size in a laser cutter, after which

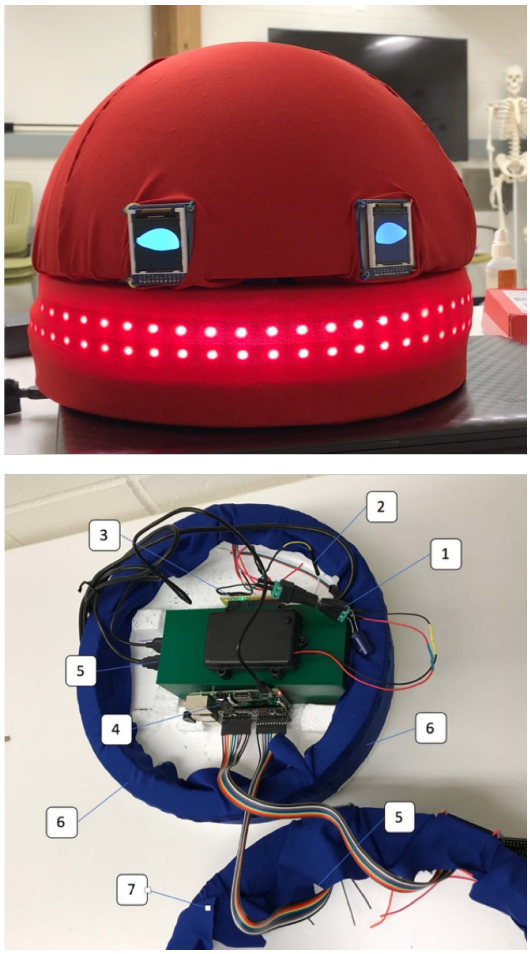

Fig. 1: The finished prototype is shown above, and the internal wiring is shown below: 1) Power connection between expressive lights and three-cell battery, 2) Data connection between Arduino and expressive lights, 3) Arduino Uno with custom hat, 4) Raspberry Pi with Snake Eyes hat, 5) Cables connected to TFT screens, 6) Bottom shell, and 7) Top shell.

the pieces are glued together to form the base of the DD. In order to have customizable color, both base and top are covered in colored lycra material.

B. Internal Control Architecture

This core is the center of computing and power distribution of the DD. The components are housed in a custom-designed and 3D printed shell that efficiently packs all the electronic components into a compact area, enabling it to fit inside of the shell. The core houses a Raspberry Pi 3 with Raspberry Pi Hat, Arduino Uno with power distribution circuit, 20100 mAh battery pack and a 3xAA (4.5V) battery pack.

C. Dynamically Unconstrained Degrees of Freedom

Two 1.4" TFT LCD screens are positioned between the dome and the base to create expressive "eyes" that establish bilateral symmetry. They are controlled the Raspberry Pi 3 by means of an AdaFruit Snake Eyes Bonnet, an accessory for the Raspberry Pi that was designed explicitly to drive two miniature displays from the same source. The eyes displayed are designed based on an "expressive eye model", explained here. In this model, we start with a base circle that for the eye that divided into the upper and lower halves. We provide specifications for the left eye, with the right eye taking a mirror image of the shape described. We change the following variables to create different eye shapes:

- Chord with clockwise degree and y axis distance
- Concave circle with percent size *c1* (upper half) and *c2* (lower half).

Additional lights comprised of an individually addressable RGD LED strip that surrounds the base of the Styrofoam shell create the desired "breathing motion" from our design. This strip is programmable and can thus be used to exhibit a different cadence and intensity (brightness) of simulated breathing. Initially, we designed a smooth pulsating simulation of breathing, but this element can be modulated to show changing internal state to a human viewer in an intuitive manner – parallel to other tasks the robot may be fulfilling.

The finished prototype is shown in Figure 1.

IV. Conclusions and Extensions

This work paves the way for ongoing user studies – both in virtual reality, where we can easily create home environments and contexts, and in hardware, bringing users into the lab and performance spaces to understand their perceptions of various settings – validating our ability to produce variable characters on the platform. This work will provide important guidance for home robot designers to ensure that user perceptions of their designs are intentional – and support the function of the product.

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