Exhibition Spaces for Human-Robot Interaction Tactile Data Collection

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Abstract

Exhibition spaces are spaces to provoke visitors with new experiences and are a potential space for exploration and conduct human subject research. This paper explores the data collected about how a robot was touched at an exhibition. The robot experiences its world through pressure sensors, responds to touch through haptic feedback and sound, and records the sensors' data for analysis. In this exhibition, the pressure sensor readings were used to control a haptic purring sensation and a sonic "scream." Visitors' interactions with the robot and each other emphasized the difference in emotional expression haptically and sonically and the conflict it can create between a participant and an observer when they do not align. The exhibition space gives visitors the opportunity to interact with a robot in a non-laboratory setting, and for researchers to collect data from their interactions. Based on the collected data, a taxonomy of gestures is proposed for a tactile interactive robot.

Keywords

Touch, Haptic Interaction, Human-Robot Interaction, Exhibition, Media Arts

Introduction

Exhibitions are a place where visitors come alone or in small groups [1] to be both educated and entertained [2]. These visitors have a diverse set of learning styles and prior learning experiences [3], while they are also primed to be open to new experiences. Art exhibition spaces can create a "honeypot effect that draws observers into the activity" [4]. There is a precedent of using art events as a place to conduct human computer interaction research [5]. Most human-robot interaction research that takes place in exhibition spaces focuses on replacing human roles at an event, like a docent [6] or barista [7]. These interactions are also focused on providing a service and/or conveying information through speech and gestures.

Touching Affectivity uses media arts to discuss the potential for embodiment and physical interaction with technology. It tests how different sonic and haptic responses of a robotic creature affect how participants touch it. This paper explores the social dynamics among the people interacting with a tactile emotive robot. It also examines how the emotional expression of a robot can be perceived as completely different by the person touching the robot than by the person observing the interaction. The paper explores the use of an exhibition context to collect data about human-robot interaction, with a coding system and sensor results that support it.

Background

Interactions with early artwork like *S.A.M.* (1968) [8] and *Toy-Pet Plexi-Ball* (1968) were based on sound. Though *Toy-Pet Plexi-Ball* could be put in a fur cover and petted, the creature did not react to touch [9]. Touch based interactive work at the time like *Magnet TV* (1965) by Nam June Paik did not have zoomorphic forms [10]. Creating artwork that can be touched has a lot of technical difficulties with sanitation, sensors and deterioration. More contemporary works like *Cybersqueeks* (1988) by Ken Rinaldo [11], *Echidna* (2002) by Tine Bech [12] and *Trou Mireia* (2017) by Donat Melús [13] explore different interfaces and interactions for touch. For example with *Cybersqueeks* the interaction is through sensors and switches [14] and with *Echidna* the electromagnetic field that the artwork creates is disturbed by touch. While *Trou Mireia* does not physically react to touch, the visitor can only see the interaction via CCTV. The work is relevant due to the haptic interaction of touching it and because it is a media artwork that has an organism-like quality. The sanitation aspect of this work is managed with the visitors wearing gloves while interacting with the work and watching themselves interact on a screen, creating a medical atmosphere and conjuring ideas of surgery and endoscopy. While a reasonable solution for some work, medical gloves do not align with the intended comforting atmosphere in *Touching Affectivity*.

HRI Taxonomies

The two main ways to analyze how humans interact with robots are through sensor readings and video annotations. Different taxonomies have been proposed for classifying human-robot interaction. Yanco et al. describe a taxonomy for different possible "combinations of single and multiple humans and robots, acting as individuals or in teams." In this project there was only one robot, so we saw a visitor interact with the robot, as well as groups of visitors making decisions together to interact with a robot in a specific way and rarely multiple humans interact with the robot at the same time independently. Scholtz describes 5 roles that a human can have when interacting with a robot [15]. Two of these roles are relevant in this study, the operators, who are directly changing

General	
Micro-controller	Teensy 3.5 and Teensy Audio Board
SD Card	32 GB SDcard
Speakers	UClear Digital Pulse Wired Drop-in Helmet Headphones
4 Vibrating Motors	Coin Vibration Motor 3V 66mA
Other	Wiring / Solder / Tape / Thread / Resistors / Prototyping Board
6 dof Pressure Sensor	
6 Pressure Sensors	Round Force-Sensitive Resistor 1/2" diameter round,
6 Foam Balls	2" Foam Squeeze Balls
Other	Stiff Linen Fabric, Modeling Clay, Liquid Electrical Tape

Figure 1: Materials required for the robot.

the robot's behavior and the bystanders who do not control the robot but have an understanding of the robot in space. Huttenrauch and Eklundh defined different modes of physical proximity, including: avoiding, passing, following, approaching and touching [16]. During the exhibition visitors displayed all of these types of proximity except for following.

The most applicable taxonomy that could be found for coding the interaction in a gallery environment was defined by Kim et al [17]. In this study passers-by were solicited to touch the robot and then interviewed on how and why they touched the robot. The study used the categories "stroking, patting, hitting, touching, poking, pushing, hugging, and grabbing" to describe different types of interactions. These were mapped into a space with one axis of positive vs negative and a second axis of emotional vs neutral. The robot in Kim's study was hard so it did not cover all the types of interactions a soft robot could record.

Design of Touching Affectivity

In *Touching Affectivity*, the creature expresses emotion through sound in response to different types of stimuli. While in an idle state, the creature makes a chirping noise that is generated by sampling a micro-controller's unconnected analog input signal. The goals of the periodic chirp are to attract visitors, to signal to them that the creature communicates vocally. The chirping is inspired by a cat's periodic mew to get its owner's attention. There are a range of ways that a visitor could touch the creature, which can be converted to sound.

The creature expresses emotion through movement and in response to touch. It has four small vibrating motors sewn into the fur that vibrate in response to pressure, and pressure sensors that can read pressure on all six sides. An increase of pressure causes an increase in vibration. The vibration references a cat purring and has been perceived that way by gallery visitors. Too much pressure causes "screaming," a high-pitched chirping noise, to deter visitors from strangling or destroying the creature. The purring vibrations stop when the pressure reaches the screaming threshold so as not to confuse the guest.

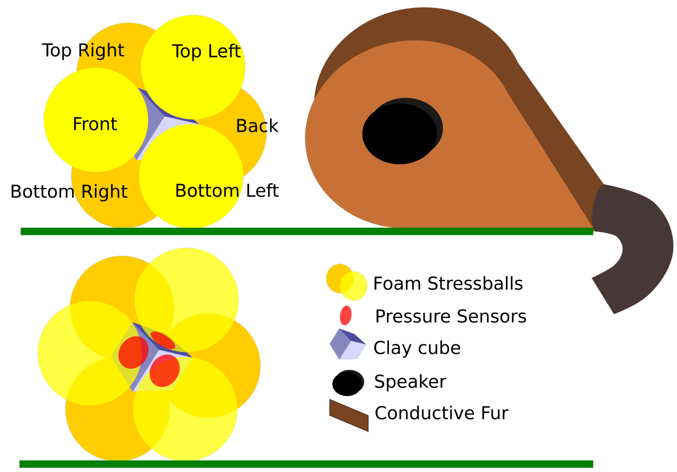

Figure 2: Construction of the robot. Top left is the 6-dimensional pressure sensor. Top right is the outside of the robot. Bottom is the 6 dimensional pressure sensor showing how the sensors are placed.

Physical Design

The robot runs on a Teensy 3.5 micro-controller with an audio board with the parts described in Figure 1. The micro-controller is outside of the robot, connected to the sensors through cables which run through the tail. Having the micro-controller separated meant that a participant would not damage it while interacting with the robot. It also made it easier to have access to the SD card, to trouble-shoot, to modify the wiring and to reprogram the board. The robot has six pressure sensors, creating one 6-degree-of-freedom (6-DoF) pressure sensor, which can sense if the front, back, left, right, top or bottom is pressed. The pressure sensors activate four vibrating motors, one in the front, one in the back and one on each side. For example, the more pressure the front pressure sensor on the robot sensed, the stronger the vibrations became from the front motor.

The robot was constructed out of a homemade 6-degree-of-freedom pressure sensor covered by a piece of synthetic fur with four vibrating motors sewn into it. The robot had two speakers attached to the outside, placed like eyes. The robot's tail contained cables that connected the sensors and speakers to the micro-controller. The squeezable design "squeeze sensor" was constructed out of six pressure sensors and foam balls [18]. Six squeeze balls were used instead of 14 as in Seum-Lim Gan's original design. The pressure cube was built by sewing pressure sensors into a fabric cover for a 1" by 1" cube of clay, instead of embedding them in a molded cube (see Figure 2). While this methodology has been used for creating a pressure controller for a musical instrument, it has not been used before for robots in this context.

Sound Generation

The sound was generated using a Teensy audio board, with an enveloped sine wave. The parameters of the tone controlled by the program are the amplitude of the sine wave and frequency of the sine wave, the sustain of the envelope and the decay of the envelope. The robot produced periodic chirping when no one was interacting with it. The robot squealed when a pressure sensor reached above 78% with a series of short high-pitched chirps until the pressure went back down, and the pressure controlled the motor vibrations which made an audible sound.

Methodology

Touching Affectivity was installed and presented at "Invisible Machine", a group exhibition on June 1st, 2018 (see Figure 3) at the University of California, Santa Barbara. More pressure created stronger vibrations, and too much pressure caused the robot to "scream." The robot also periodically chirped because of the random signal coming into the unplugged touch sensor input. A GoPro was hung above the pedestal recording visitor movement, speech, and interaction through the space for 3 hours and 35 minutes of the exhibition. During this period of time there were approximately 198 instances where a person approached the robot, touched it, and left. Because there was no interview process or survey the demographic information including age group is unknown. The quotes in the results section are drawn from the video recorded during the exhibition.

To meet the University of California, Santa Barbara's Institutional Review Board (IRB) ethical requirements for research, a stand with information sheets about the work was located directly next to the work. We have included the information sheet text in Appendix A. The information sheets explained that by interacting with the robot, they are consenting to be recorded for research purposes. Due to the public nature of the media arts exhibition this was deemed adequate by the IRB.

After the exhibition, the video recording was coded using ELAN [19]. First, the interactions were coded to describe how the visitors were interacting with the robot. Then each physical interaction a participant had with the robot was rated as either, "gentle," "medium," or "rough." "Gentle" was used to code interactions where the person lightly pets, taps, or runs their finger across the robot. "Medium" included when a person holds and lightly squeezes the robot, with attention paid to the person's fingers for light squeezing, pets or taps the robot a little more than "gently." "Rough" is when the person scratches the robot, presses the robot against themselves or the stand, or squeezes the robot hard. For each annotation one keyword was used. If the person switched actions while interacting with the robot, they were recorded as two separate events.

Results

Video data of the interactions was recorded for 3 hours and 35 minutes of the 5 hours and 31-minute exhibition. The video recordings of these interactions produced the most interesting results. During this period of time, there were approximately 198 instances where a person approached the robot, touched it, and left. Out of 616 interactions, 188 of the interactions were coded as gentle, 264 of the interactions were coded as medium, and 164 of the interactions were coded as rough.

Figure 3: Demonstration of "Touching Affectivity" at a group exhibition on June 1st, 2018. The right two images were taken by the ceiling mounted GoPro from the exhibition. The visitors in these photographs gave written consent to having these photographs published.

The work in many ways was a conversation piece. The video camera included an audio recording. People frequently explained and showed different ways to interact with the robot to each other. There were some interesting group dynamics. At one point, a group of three people all squeezed the robot at once. Because the robot was quiet in a loud environment, people would hold it up to their ears. During the recording, 5 people took photographs or videos of the robot.

Embodiment

Though some did not see the robot as a creature, one stating that they were "touching a furry object" while recording themselves, most people treated the robot like it was an animal, comforting it when it had been punched and discussing it like it had feelings and could feel pain. The robot had a face, a consistent texture and it moved, all signifiers of an animate creature. People empathized with the robot as described below. While the interaction with the robot was viewed as uncomfortable, the physical appearance did not seem to bother any of the participants. Visually, people viewed it as animal-like. They commented on the robot's embodiment, comparing it to a Furby, a child's toy, or a tribble, a creature from Star Trek. One woman was very vocal about it being like a tribble and how much she liked it. In response to the tail one person said, "Oh, it's got a tail! I really like the tail," and another said, "It's like a brain with a spinal cord." While the design did actively reference the idea of a tribble, visual metaphors, like a brain and spinal cord were apt but unintentional.

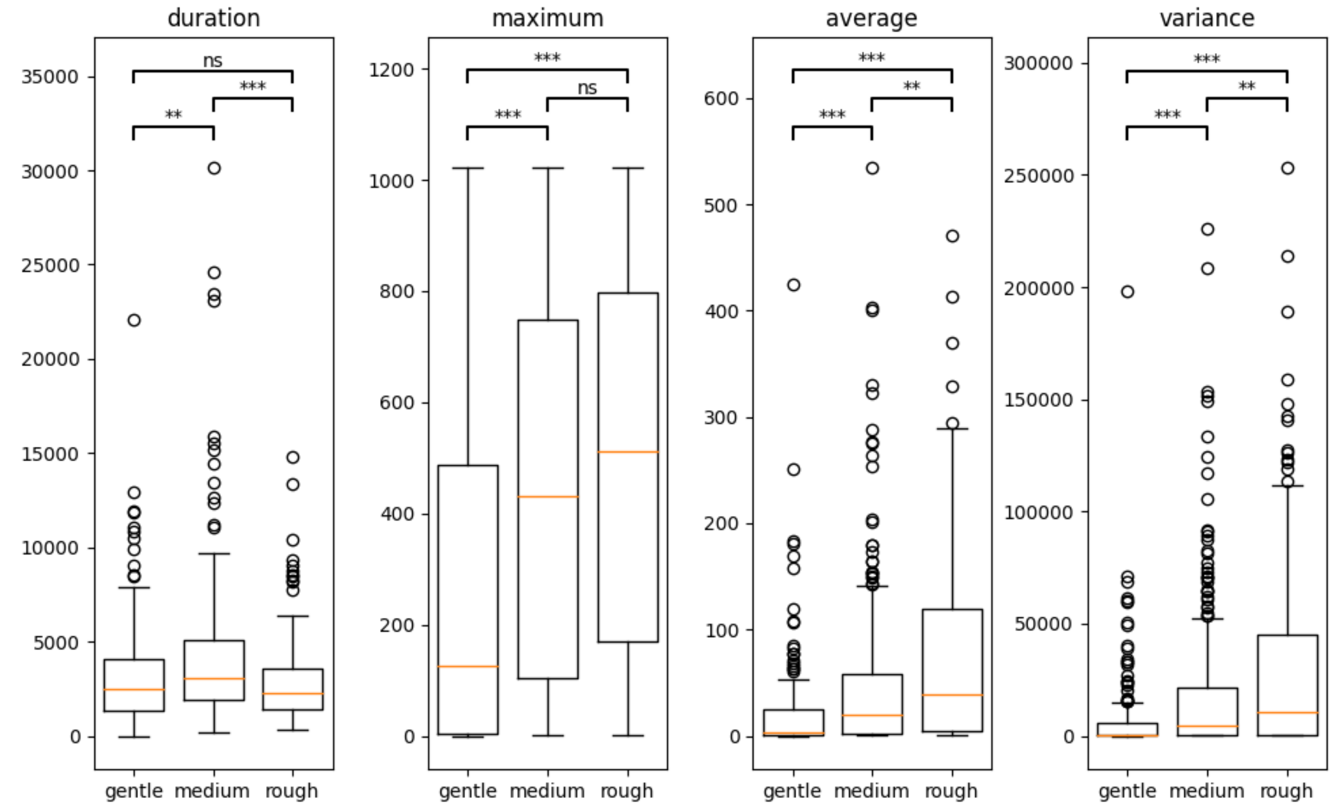

Figure 4: Four measurements were calculated per annotation. A box and whisker plot is included for each measurement. Duration, calculated in milliseconds, was the length of the annotation. Maximum was the max signal the pressure sensors received during the annotation. The sensor values ranged from 0 to 1024. The average and variance of the signal values were also calculated.

Aggressive and Empathetic Behavior

This work's sonic response and tactile response caused participants to be uncomfortable with the way that others handled the robot. Many people referred to the vibrations as purring and were confused that when squeezing it, it felt like it was purring very hard haptically, but sonically it sounded like it was in pain. The person who was squeezing the robot experienced the vibrations of the robot as they increased their grip's pressure. They experience it as a purring sensation or vibration, which in a feedback loop makes them squeeze more because the robot purred harder. When the robot began to make a high-pitched screaming noise that was supposed to tell people they shouldn't be squeezing it that hard, they had already interpreted the vibrations as purring and, because the robot was still vibrating, interpreted the sound as positive. However, a person who was witness to this interaction heard the pain sound but did not feel the vibrations, so they viewed the other person as inflicting pain on an animal.

There were some unexpected and sometimes violent interactions. People shook the robot, tossed it back and forth between two hands, tried to tie it in a knot, hugged the robot tightly, punched the robot, and threatened to throw it. Because audience members viewed and treated the robot like an animal some wanted it to be happy. At one point, after seeing a boy punch the robot and walk away, a girl walked over, petted it, and hugged it.

This work created conflicting perceptual cues, some of which were only perceived by the participant holding the robot. The difference in experience between the person interacting with the robot and the person watching them created a conflict. Groups would argue and discuss the emotion that the robot was expressing. There were arguments between people in groups about whether squeezing it was "hurting it" or making it happy because it was purring. While a group of 5 people interacted with it, a conversation about the work included, "No, you are hurting it," "Whoa, this is so cool," "Make it purr," "Make it vibrate," and "It's kind of purring." This emphasized the importance of tactile and sonic synchronicity.

Some viewed this as the artist/researcher attempting to trick them into causing pain on the robot. Some visitors were worried about how they would be perceived by researchers. People commented about the user study and spoke to one another about it. After learning that they were being recorded one person said, "I was squeezing it. They are probably going to think I am evil." Other participants after reading the description were still physically aggressive with the robot. One visitor especially liked the work stating it was the most interesting piece in the exhibition, viewing it as a test to see how violent someone would be with a robot when trying to make it respond. In the video he came back to the work multiple times with different people.

Signal Analysis

The signal data from the six sensors was used to see if there was a connection between the video annotations and the pressure that the robot received. For each annotation, all six signals were used to calculate one summary value. There were three calculations completed per annotation: the maximum, average and variance of all signal values.

The Kruskal-Wallis H-test indicated that there are differences between the duration ($\chi^2(2)$ =17.65, p=1.467e-4), maximum ($\chi^2(2)$ =50.79, p=9.353e-12), average ($\chi^2(2)$ =61.45, p=4.530e-14) and variance ($\chi^2(2)$ =59.32, p=1.311e-13) in signal among gentle, medium, and rough. A pairwise post-hoc Dunn test with Bonferroni adjustments for duration was only significant for gentle vs. medium (p = 0.013) and medium vs rough ($p < .001$). A pairwise post-hoc Dunn test with Bonferroni adjustments for maximum was only significant for gentle vs. medium ($p < .001$) and gentle vs rough ($p < .001$). A pairwise post-hoc Dunn test with Bonferroni adjustments for maximum was significant for gentle vs. medium ($p < .001$), medium vs rough (p = .0111), and gentle vs rough ($p < .001$). A pairwise post-hoc Dunn test with Bonferroni adjustments for maximum was significant for gentle vs. medium ($p < .001$), medium vs rough (p = .0301), and gentle vs rough ($p < .001$).

These results show that this coding methodology does correlate with different types of interactions. While there is not a significant difference in the maximum values of medium and rough interactions, on average, the rough values are significantly larger and more varied than the medium interactions. The interactions coded as medium were also significantly longer than the rough interactions. While the gentle and rough interactions were not significantly different in duration, overall, the gentle signal was significantly different from both the medium and rough coded interaction signal for maximum value, average value, and variance.

Discussion

The videos from the "Invisible Machine" exhibition produced interesting results when the emotion expressed conflicted at the tactile and sonic level. At the exhibition, people were interested in discussing the work conceptually. The conflict created by the installation was viewed as meaningful by visitors.

The results of the exhibition express the importance of aligning the sonic and tactile emotive responses when designing multi-modal interactions. It also further emphasizes the importance of the context of the response. In this work the sonic response was paired with a tactile response instead of a visual response. Because the tactile response was only experienced by the visitor touching the robot, the context of their interaction with the robot was different from someone who simply observed, so they interpreted the sonic response differently. This shows that the same sound can be interpreted differently with the addition of a haptic response.

Touching Affectivity shows the difference between intimate and personal interactions. This work emphasizes that there can be a large perceived difference between an intimate interaction with a robot compared to the personal interaction with it as seen in the video recordings. The way that the onlooker viewed the interaction and the robot's expressed emotion was diametrically opposed to the experience of the person intimately interacting with the robot.

There are many directions this work can be taken in the future. A systematic study could be done to test the perceived emotion of different responses, comparing the interpretation of algorithmically generated sound responses to randomly generated sound responses, and composed sound responses. A second systematic study, which would include a haptic response is the next step, comparing haptic + generative sound, haptic + neutral sound, haptic only, generative sound only, and neutral sound only.

Conclusion

Touching Affectivity explored the conflict between haptic and sonic response. At the exhibition it explored how people handled being told that a less reactive robot would sonify the way it was touched. The viewers were told that the robot would sonify the way it was touched, but the robot only responded sonically to being squeezed extremely hard. The robot also vibrated softly with increasing intensity when squeezed. This conflict between the harsh sound and soft vibration created an interesting quandary in the people who interacted with the robot. The positive reinforcement of purring and the lack of a sonic response until high pressure was felt by the robot caused participants to squeeze the robot with as much pressure as possible. Because they had to squeeze hard to get a sonic response, they felt that it was appropriate to touch it in more aggressive ways. A conflict was created because the viewer heard the sonic response of pain when the robot was squeezed, and the participant experienced the haptic response of purring.

The robot in *Touching Affectivity* can be used to find meaningful information about how we interact haptically with a robot that sonifies the way it is touched. It emphasizes the difference in experience between personal and intimate spaces and the conflict it can create. This work shows that sonic and haptic responses need to be aligned, and the distinction between interaction in the intimate and personal spaces. It has applications for robots in the home, children's toys, and emotional support robots. It also emphasizes the importance of touch in the arts, and that artwork that is intended to be interacted with can lose its meaning when the ability to touch is taken away.

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Appendix A: Information Sheet

Below is the information sheet that was provided to visitors who interacted with the robot.

PURPOSE:

You are being asked to participate in a research study. The purpose of the study is to see how a furry robot's sounds and vibrations effects the way a person interacts with a robot.

PROCEDURES:

By interacting with this robot you are choosing to participate in the study. Please touch and/or pick-up the robot. You may interact with the robot for as long or little as you would like. A camera with a microphone is set up above the robot to record how you interact with it. Because the camera is mounted from above it will not record faces.

RISKS:

By participating in the study you are agreeing to be recorded. Data will be stored on a secure server hosted at the University of California, Santa Barbara. No personal identifiers (e.g., names) will be recorded as part of the research. We take reasonable measures to protect the videos from unauthorized access, use or disclosure. The videos will be retained for future analysis.

BENEFITS:

There is no direct benefit to you anticipated from your participation in this study.

CONFIDENTIALITY:

Absolute confidentiality cannot be guaranteed, since research documents are not protected from subpoena. Non-identifiable videos (e.g., no faces) will be retained for future analysis. Other researchers may view the videos for analysis purposes.

EMERGENCY CARE AND TREATMENT FOR INJURY:

If you are injured as a direct result of research procedures, you will receive reasonably necessary medical treatment at no cost. University of California, Santa Barbara does not provide any other form of compensation for injury.

RIGHT TO REFUSE OR WITHDRAW:

You may refuse to participate by not interacting with the robot. You may stop interacting with the robot at any time.

QUESTIONS:

If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact:

Hannen Wolfe, wolfe@mat.ucsb.edu