The Haptic Creature Project: Social Human-Robot Interaction through Affective Touch

Steve Yohanan[1] **(student)** and **Karon E. MacLean**[1]

Abstract. The communication of emotion plays an important role in social interaction. Research in affective display both in the social sciences and in social human-robot interaction has focused almost exclusively on the modalities of vision and audition; however, touch has received disproportionate attention. This paper presents an overview of the Haptic Creature project, where we seek to develop a deeper understanding of affect display through touch in the context of social interaction between human and robot. We also hope to gain knowledge on the role affective touch plays in supporting companionship. Drawing from studies on human-animal interaction, we are developing the Haptic Creature, a robot that mimics a small pet that interacts solely through touch. Details of the robot and related user studies are presented.

1 INTRODUCTION

In this paper we present an overview of the Haptic Creature project. The overall goal of our project is to investigate the use of affective touch in the social interaction between human and robot. We are specifically interested in the display, recognition, and influence of this form of touch. Additionally, we are interested in the role affective touch plays in fostering companionship between human and robot.

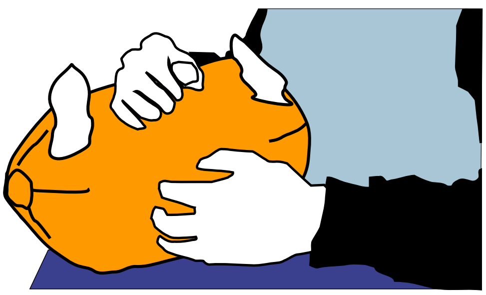

Figure 1. Human interacting through touch with Haptic Creature on lap.

Our approach is to leverage research in human-animal interaction by developing a robotic creature that mimics a small animal, such as a cat or dog, sitting on a person's lap (Figure 1). Dubbed the Haptic Creature, the robot interacts with the human solely through the modality of touch. In addition, we are developing a series of user studies that utilize the Haptic Creature to further the goals of the project. Both the robotic creature and the user studies will be discussed in further detail.

The structure of this paper is as follows. It begins with coverage of related work and motivation behind the project. The paper continues with specifics of the Haptic Creature robot. It then presents an overview of user studies being conducted as part of the project. Finally, the paper concludes with a brief summary of what has been covered.

[1] Sensory Perception and Interaction Research Group (SPIN); Department of Computer Science; University of British Columbia; Vancouver, Canada; yohanan@cs.ubc.ca, maclean@cs.ubc.ca

2 BACKGROUND

The Haptic Creature project draws from a variety of seemingly disparate research areas: socially interactive robotics, affect, touch, as well as human-animal interaction (Figure 2). From the perspective of these areas, this section introduces the related work and motivation behind the project, then concludes by differentiating the project from similar research.

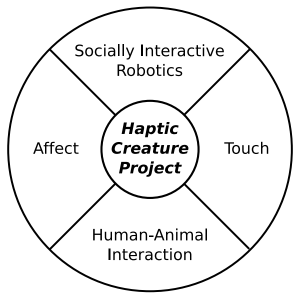

Figure 2. Research areas related to the Haptic Creature project.

2.1 Socially Interactive Robotics and Affect Display

Socially interactive robotics is a subfield of human-robot interaction studies. Fong *et al.* [8] describe socially interactive robots as ones "for which social interaction plays a key role ... [in order] to distinguish these robots from other robots that involve 'conventional' human-robot interaction, such as those used in teleoperation scenarios."

An important aspect of social interaction is *affect display*—the external manifestation of internal emotional state—as it helps to regulate and add significance to the interaction [4]. The two most studied modalities for affect display in humans are vision and audition.

In the case of vision, the use of facial expressions is commonly used to convey emotion [6], so is not surprising that affect display in socially interactive robotics similarly concentrates on facial expression (e.g., [3] [15] [12] [17]). As for audition, prosody of speech is used in affect display. Likewise, this means has also seen investigation within socially interactive robotics (e.g., [2] [18]).

2.2 Affective Touch and Human-Animal Interaction

One modality for affect display that has received much less attention than vision and audition, however, is that of touch [11]. The sense of touch is rather unique: the skin is the largest organ in the human body, the first sense organ to develop, and it plays a major role in early development [14]. Furthermore, touch is proximal; requiring close or direct, physical contact to sense [10].

Affective touch can be defined as touch that communicates or evokes emotion. General studies on interpersonal touch, however, have shown various confounding factors such as gender, familiarity, social status, and culture (e.g., [7] [13] [16] [23]). Additionally, these sorts of studies have been found to cause significant levels of participant discomfort (e.g., [22]). In an attempt to avoid these issues, the Haptic Creature project has chosen to draw from models of interaction, not between humans, but between human and animal.

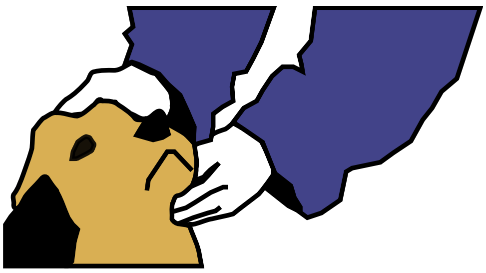

Figure 3. Human interacting with dog through touch.

It is our hope that human-animal touch will be less loaded. Likewise, there already exists a wealth of non-verbal communication—especially through touch (Figure 3)—between human and animal [5] [1]. Also, the long history of human-animal bonds [19] is in keeping with one of the research goals to investigate the influence of affective touch on companionship.

2.3 Differentiation

When filtered through the various research areas presented above, there are several projects that overlap with the Haptic Creature. Most notable are the small set of social robots combining touch interaction and animal-like form: Shibata's baby seal, Paro [20]; Stiehl's teddy bear, the Huggable [21]; and Sony's dog, Aibo [9]. This section covers some of the more significant differentiating factors in relation to these three robots. The rationales behind these factors are given more detail in Section 3.1.

Perhaps the primary differentiation of the Haptic Creature project is its strong concentration on the modality of touch for affect display. The Huggable is the only other device possessing full-body sensing; Paro and Aibo both have only limited interaction points for touch input. Moreover, each of these three projects focuses much less on touch for affect display originating from robot itself; rather, they rely more on visual and auditory expression.

A second differentiating aspect of our project is the level of zoomorphism. The Huggable, Paro, and Aibo all, to varying degrees, have clearly defined features and overall shape. While our goal is that the Haptic Creature be recognizable as animal-like, it is consciously designed to have a more amorphous appearance.

3 THE HAPTIC CREATURE

The Haptic Creature (Figure 4) is a robotic device that mimics a small lap animal, such as a pet cat or dog. It is composed of five major components: a body, two ear-like appendages, a breathing mechanism, a purring mechanism, and a warming element.[2] The creature interacts with the world solely through the modality of touch and regulates its emotional state based on this interaction. For example, a human sitting with the creature on her lap gently strokes it. The Haptic Creature may consider this a pleasing interaction, thereby updating its emotional state to reflect happiness. In turn, the creature then renders this by brisk, rhythmic breathing (causing its ribcage to press and release against the human's hand); stiffening its ears; and a gentle purring vibration.

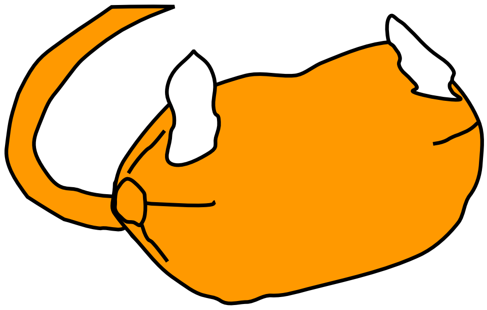

Figure 4. The Haptic Creature.

This section provides further details of the Haptic Creature. It includes coverage of design considerations, phases of development, and an architectural overview of the creature.

3.1 Design Considerations

There are three major design considerations for the Haptic Creature. The first is that the interaction centers around the modality of touch. We are concerned with affect display through touch. As a result, all communication of emotional state from the creature is haptic. Similarly, all sensing by the robot is touch-based. The second consideration deals with providing an organic interaction whereby the sensing and, especially, the affect display seem as a coordinate whole. We are trying to avoid the robot being perceived simply as a "bag of tricks:" a random and unrelated set of actuations. The final design consideration is in the level of zoomorphism. Our approach is to borrow from human-animal interaction; however, we are not attempting to construct a lifelike replica of an existing animal. The creature's form is intentionally minimalistic. Likewise, its interactions should not be limited to that of a single species.

[2] A non-functioning tail simply conceals cables to the creature from the host computer.

3.2 Development Phases

Development of the Haptic Creature is being conducted in three stages: a Wizard of Oz prototype, an automated prototype, and a final device. This section presents these stages in turn.

3.2.1 Wizard of Oz Prototype

The initial phase of development has already been completed. It was a Wizard of Oz prototype (Figure 5), with all interaction controlled by a human operator. The majority of its effectors are controlled pneumatically, and all sensing is through visual observation of the operator. This version allowed us the ability to quickly explore the idea of affect display through touch within the context of human-animal interaction. Full details of its construction and related user study were presented in [24].

Figure 5. Wizard of Oz prototype. (Photo: Martin Dee)

3.2.2 Automated Prototype

The current stage of development is an automated prototype. This version furthers concepts explored with the initial prototype while obviating the need for human operation. The automated prototype is similar in outward form to the Wizard of Oz prototype (Figure 5). It will sense touch across its entire body (including ears), and effectors will be manipulated via servos and motors (Figure 6). This stage is being used for rapid implementation and testing of software, hardware, and interaction techniques. Automation techniques are being tested and enhanced through successive iterations to evolve into a more robust device (Section 4.2).

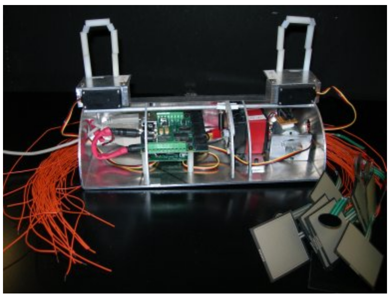

Figure 6. Internals of Haptic Creature showing chassis containing electronics and mechanical components used for sensing and actuation.

3.2.3 Final Creature

After multiple iterations of the automated prototype, a final Haptic Creature will be constructed. The goal is that a majority of the software architecture will be reused; however, more robust hardware elements may be introduced at this stage.

3.3 Architecture

A high-level overview of the Haptic Creature architecture is shown in Figure 7. This section provides a description of the five major components depicted: low-level sensing, gesture recognizer, emoter, physical renderer, and low-level actuation.

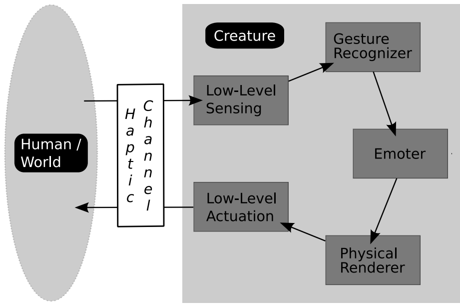

Figure 7. Overview of the Haptic Creature architecture. Human (left) interacts with the Haptic Creature (right) solely through touch. This input passes through the various components of the creature, eventually resulting in an appropriate haptic response to the human.

3.3.1 Low-Level Sensing

This component handles the aspects of the platform that deal with sensing information from the real world. It consists of physical sensing hardware as well as the programmatic aspects that read the data these sensors provide. This component does little interpretation of the data, save perhaps simple filtering and normalization. One example would be a force-sensing resistor that modifies its value based on pressure.

3.3.2 Gesture Recognizer

This component takes information from the *low-level sensing* component and constructs an initial model of the physical data. Its function is to manage the variety of sensor information so as to provide a cohesive view. One example would be an array of pressure sensors that, when monitored, allow determination of direction and speed of movement along with pressure intensity.

This component, in turn, builds a higher-order model of the input data. An example would be distinguishing between a hard stroke and a soft pet. Both require monitoring the direction, speed, and pressure intensity across a range of sensors; however, this component also interprets these values such that an evaluation of the intention of the user can be determined.

3.3.3 Emoter

This component represents the underlying emotional state of the platform. This state is affected either externally through information from the *gesture recognizer* or by means of its own internal mechanisms (e.g., temporal considerations). One example would be a soft pet elicits a *pleasured* state in the device while gradually decaying into a *neutral* state shortly after this interaction ceases. This component itself has no knowledge of the recognizer and only cursory knowledge of the renderer (necessary for change notification). This allows the model to focus on the domain-specific information of the system without being directly concerned with how it is getting its information or how its state is being presented.

3.3.4 Physical Renderer

This component is in charge of the higher-order, physical manifestation of the internal state of the platform. The component listens for changes in the *emoter* component, then translates the results into an orchestrated manipulation of the effectors. One example might be that when the platform moves into a *pleasured* state its breathing response adjusts to very soft, rhythmic in/out motions while it produces a similar "purr" that can be felt.

3.3.5 Low-Level Actuation

This component is tightly coupled with the *physical renderer* component. It is charged with directly interfacing with the platform's effectors. It does little interpretation of the information, save perhaps adjusting normalized data appropriately for individual hardware devices. One example would be setting the position of a motor.

4 USER STUDIES

The main goal of the Haptic Creature project is to investigate the use of affective touch in socially interactive robotics. We are especially interested in the display, recognition, and influence of this form of touch. To that end, we are developing a suite of studies that examine the interaction between humans and the Haptic Creature. An overview of these studies is presented in this section.

4.1 Preliminary Investigation

This first study has already been completed. It was a preliminary exploration of affective touch employing our Wizard of Oz prototype (Section 3.2.1). We learned that emotion can be clearly communicated through primarily haptic means, and that this communication affects the recipient. The study also bolstered our case for the use of human-animal interaction models as a means to explore affective touch. Details of the study were presented in [24].

4.2 Interaction Decomposition

The cyclic interaction between a human and the Haptic Creature is decomposed in Figure 8. Throughout the current development of the automated prototype (Section 3.2.2) various studies will be conducted that concentrate on the direct interaction between human and creature.

The interaction is divided into its component parts, so the studies themselves become additive. We begin by isolating on a specific cell—e.g., studying the variety of gestures a human uses in the display of affective touch (cell 1)—then a subsequent study examines the interaction across two cells—e.g., the output of affective touch from the human, and the ability of the creature to correctly recognize it (cells 1→2). The goal is to characterize low-level aspects of the interaction, then use these to construct higher-order models, eventually ending with an understanding of the entire interaction cycle.

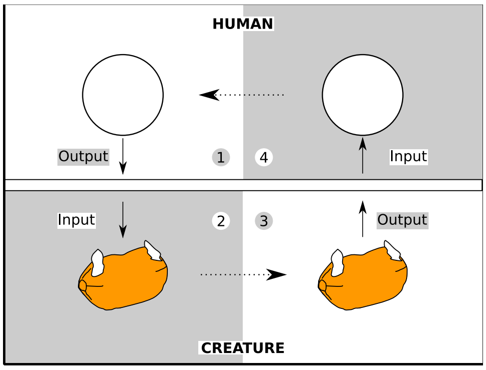

Figure 8. Interaction loop between human and Haptic Creature. Solid lines between cells represent a display of affect touch. Dashed lines denote an internal update of emotional state as a result of the interaction.

4.3 Companionship

Once development of the Haptic Creature is complete (Section 3.2.3), a final user study will be conducted. The goal of this study is to gain a deeper understanding of the role affective touch plays in companionship. Its focus is less on the form of interaction and more on the effects. That is to say, the manner in which the interaction is conducted is the focus of the previous studies, while the emotional result of the interactions is what this study encompasses. It will likely take the form of longitudinal tests, where participants will interact with the Haptic Creature over an extended period.

5 CONCLUSION

In this paper we have presented an overview of the Haptic Creature project, whose goal is to investigate the display, recognition, and influence of affective touch in human-robot interaction. In an attempt to avoid various issues in studies on interpersonal touch, our project draws insight from models of human-animal interaction. We have presented details of the Haptic Creature, an animal-like robot we are developing to interact exclusively through touch. We also presented an overview of user studies employing the Haptic Creature.

5.1 Grace Note

As noted in Section 2.2, studies on the general nature of interpersonal touch have at times proven difficult. Likewise, human-animal studies can require considerable effort in the control of factors. Though our research examines affective touch in the context of interaction between human and robot, there is hope that some insights gained may be applicable to interpersonal or human-animal interaction. As one example, our Haptic Creature may be employed in preliminary hypothesis testing or pilot studies of interpersonal or human-animal interaction (cf. Section 3.1 of [8]).

ACKNOWLEDGEMENTS

We would like to thank Mavis Chan, Jeremy Hopkins, Haibo Sun for their contributions to the original Wizard of Oz prototype and user study. We would also like to thank Tim Oxenford and Sandra Yuen for their work on the preliminary phase of the automated prototype. Finally, we would like to thank members of the SPIN Research Group for their varied knowledge and ongoing support.

REFERENCES

[1] Alan Beck and Aaron Honori Katcher, *Between Pets and People: The Importance of Animal Companionship*, Purdue University Press, West Lafayette, Indiana, USA, 1996.

[2] Cynthia Breazeal, 'Emotive qualities in lip-synchronized robot speech', *Advanced Robotics*, **17**(2), 97–113, (May 2003).

[3] Cynthia L. Breazeal, *Designing Sociable Robots*, MIT Press, Cambridge, Massachusetts, USA, 2002.

[4] Joseph J. Campos, Donna L. Mumme, Rosanne Kermoian, and Rosemary G. Campos, 'A functionalist perspective on the nature of emotion', *Monographs of the Society for Research in Child Development*, **59**(2/3), 284–303, (1994).

[5] Charles Darwin, *The Expression of the Emotions in Man and Animals*, John Murray, London, England, 1872.

[6] Paul Ekman and Wallace V. Friesen, 'Constants across cultures in the face and emotion', *Journal of Personality and Social Psychology*, **17**(2), 124–129, (February 1971).

[7] Jeffrey D. Fisher, Marvin Rytting, and Richard Heslin, 'Hands touching hands: Affective and evaluative effects of an interpersonal touch', *Sociometry*, **39**(4), 416–421, (December 1976).

[8] Terrence W Fong, Illah Nourbakhsh, and Kerstin Dautenhahn, 'A survey of socially interactive robots: Concepts, design, and applications', Technical Report CMU-RI-TR-02-29, Robotics Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA, (December 2002).

[9] Masahiro Fujita and Hiroaki Kitano, 'Development of an autonomous quadruped robot for robot entertainment', *Autonomous Robots*, **5**(1), 7–18, (March 1998).

[10] *The Psychology of Touch*, eds., Morton A. Heller and William Schiff, L. Erlbaum, Hillsdale, New Jersey, USA, 1991.

[11] Matthew J. Hertenstein, Julie M. Verkamp, Alyssa M. Kerestes, and Rachel M. Holmes, 'The communicative functions of touch in humans, nonhuman primates, and rats: A review and synthesis of the empirical research', *Genetic, Social & General Psychology Monographs*, **132**(1), 5–94, (February 2006).

[12] Hiroshi Kobayashi, Fumio Hara, and Akira Tange, 'A basic study on dynamic control of facial expressions for face robot', in *Robot and Human Communication, 1994. RO-MAN '94 Nagoya, Proceedings., 3rd IEEE International Workshop on*, pp. 168–173. IEEE, (July 1994).

[13] Brenda Major and Richard Heslin, 'Perceptions of cross-sex and same-sex nonreciprocal touch: It is better to give than to receive', *Journal of Nonverbal Behavior*, **6**(3), 148–162, (March 1982).

[14] Ashley Montagu, *Touching: The Human Significance of the Skin*, Perennial Library, New York, New York, USA, 1986.

[15] Lola D. Ca namero and Jakob Fredslund, 'How does it feel? emotional interaction with a humanoid lego robot', *Socially Intelligent Agents: The Human in the Loop. Papers from the AAAI Fall Symposium*, 23–28, (2000).

[16] Tuan Nguyen, Richard Heslin, and Michele L. Nguyen, 'The meanings of touch: Sex differences', *Journal of Communication*, **25**(3), 92–103, (September 1975).

[17] Mark Scheeff, John Pinto, Kris Rahardja, Scott Snibbe, and Robert Tow, 'Experiences with sparky, a social robot', in *Workshop on Interactive Robotics and Entertainment*, Pittsburgh, Pennsylvania, USA, (April 2000). AAAI Press.

[18] Matthias Scheutz, Paul Schermerhorn, James Kramer, and David Anderson, 'First steps toward natural human-like hri', *Autonomous Robots*, **22**(4), 411–423, (May 2007).

[19] James Serpell, *In the Company of Animals: A Study of Human-Animal Relationships*, Cambridge University Press, Cambridge, England, 1996.

[20] Takanori Shibata, Teruaki Mitsui, Kazuyoshi Wada, Akihiro Touda, Takayuki Kumasaka, Kazumi Tagami, and Kazuo Tanie, 'Mental commit robot and its application to therapy of children', in *Advanced Intelligent Mechatronics, 2001. Proceedings. 2001 IEEE/ASME International Conference on*, volume 2, pp. 1053–1058. IEEE/ASME, (July 2001).

[21] Walter Dan Stiehl, Jeff Lieberman, Cynthia Breazeal, Louis Basel, Levi Lalla, and Michael Wolf, 'Design of a therapeutic robotic companion for relational, affective touch', in *Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on*, pp. 408–415, (August 2005).

[22] David N. Walker, 'A dyadic interaction model for nonverbal touching behavior in encounter groups', *Small Group Research*, **6**(3), 308–324, (August 1975).

[23] Frank N. Willis Jr. and Helen K. Hamm, 'The use of interpersonal touch in securing compliance', *Journal of Nonverbal Behavior*, **5**(1), 49–55, (September 1980).

[24] Steve Yohanan, Mavis Chan, Jeremy Hopkins, Haibo Sun, and Karon MacLean, 'Hapticat: Exploration of affective touch', in *ICMI '05: Proceedings of the 7th International Conference on Multimodal Interfaces*, pp. 222–229, New York, New York, USA, (October 2005). ACM Press.