Emotional Communication and Implicit Control through Touch

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1 Introduction

For ten years, an interdisciplinary group at UBC has been exploring the intersection of emotion and touch. This work began with some of the first carefully controlled studies of emotional response or preference to manual controls [18, 17]; of user's ability to communicate and read emotion through a simple force-feedback link that used metaphor and a representation of proximity to create an expressive space [16]; and social person-to-person touch for attention-getting [1]. Meanwhile, interaction using sensed affective state was being pioneered in the context of Human-Robot Interaction (HRI), where a user's surprise or alarm about the movements of a robot within the user's workspace was used to mediate the robot's behaviour [13].

More recently, we have pursued complementary goals of (a) closely observing how humans prefer to, and are able to, convey and read emotion through their sense of touch with an artificial animal model; and (b) designing interfaces that use a user's sensed emotional state to *implicitly* (without conscious intention or attention) control an interaction, often with a tactile component of either state feedback or a primary display.

In this abstract and talk, we will briefly overview three examples of this research. First, we present the Haptic Creature, a touch-centric robot pet designed to investigate the role of affective touch in social human-robot interactions, and summarize our steps towards defining its emotional model. Second, we describe an application that employs the Haptic Creature as an emotionally potent display, together with physiological sensors as implicit user input, as a means of interactive, fine-grained anxiety management. Finally, we take the idea of affect-driven implicit control another step towards creating devices that "just do what you want them to", while investigating touch as a channel for unintrusive feedback for a noisy control signal.

2 The Haptic Creature

The ability to communicate emotion plays an important role in social contexts by adding significance to the interaction [2]. Within social psychology, the study of affect display has focused mainly on vision and audition, while the modality of touch has received significantly less attention [11]. Recent studies, however, have demonstrated that humans are capable of communicating distinct emotions through touch [10, 16, 9].

Emotional expression research in socially interactive robotics has aligned with counterparts in psychology and sociology and, consequently, has shared those areas' emphasis on visually and aurally perceived behaviors. In the Haptic Creature project, we are motivated by the importance of emotional expression in social human-robot interaction; however, our investigation centers on affect display through the less-explored modality of touch. We focus on the expression, recognition, and emotional influence of affective touch.

Our approach is to leverage research in human-animal interaction by developing a robotic pet that mimics a small animal, such as a cat or dog, sitting on a person's lap. Dubbed the Haptic Creature, our robot interacts with the human through the modality of touch [19]. An array of touch sensors over its body coupled with an accelerometer allow the robot to sense being touched, while it displays it emotional state through adjusting the stiffness of its ears, modulating its breathing, and presenting a vibrotactile purr [20].

To systematically study the interplay between human and robot in the course of affective touch, we decomposed the overall interaction into its constituent parts. We have conducted studies exploring the ability of the Haptic Creature to communicate its emotional state to the human [21]; how humans communicate emotional state through touch to the Haptic Creature and their expectations of the robot's reactions [22] using a Wizard of Oz simulation; and, finally, the influence of affective touch interaction on the human's emotional state.

In our next steps in this research, we plan to advance our machine-learning processing of the Creature's touch sensor input [3] to recognize gestures and perhaps infer some degree of emotional state from those gestures. With this element in place, we can implement a closed-loop emotion model allowing the Creature to both read and display emotion at interactive rates.

3 Anxiety Mediation Through Touch

Learning emotional self-regulation is an accepted element of anxiety management techniques such as Cognitive Behavioral Therapy (CBT) [12]. Practicing self-regulation training activities, however, requires a level of cognitive development that is less accessible for younger children [12]. In this project, our goal is to make the learning of self-regulation accessible to children by building upon their abilities and needs, and exploiting the sense of touch as a promising channel for the communication of emotion [5]. Our approach is to engage the child in a haptically rich, emotionally expressive interaction with a version of the Haptic Creature that is responsive to the child's physiologically measured emotional state. The robot behaves in a way that rewards patience and promotes self-regulation.

In early pilots, the Haptic Creature had a comforting effect (biometric and self-reported) on adults as they watched disturbing im-

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ages. Further pilots suggested that adult participants were able to breathe at different rates with the robot by following its movements, and, separately, that changing the Haptic Creature's movement patterns appeared to alter physiological state even if participants were not instructed to follow the movements [6].

While our many informal demonstrations of the Creature to children left no doubt as to its appeal and expressiveness, controlled study with children of the target pre-teen age group revealed many challenges in both triggering anxiety and reliably validating subjective responses; pilots did not produce objective evidence of effects that appeared to be present. Building on the insights gained from these pilot studies, we decomposed the larger research question of efficacy in anxiety mitigation, as well as optimizing the Creature's interaction design for this purpose, into a series of smaller steps, some of which can be explored with adults.

In the first of these, we studied the effectiveness of a stroking tactile interaction in relaxation, in the absence of an explicit controlled stressor. In agreement with the literature on affective touch [22] and human-animal interaction [7], both biometric and self-report results showed that interacting with the Haptic Creature significantly lowered stress and increased "happiness". These results will ground the basis for exploring other forms of interaction in an iterative design cycle.

4 Implicit Control with Haptic Notification

Human cognitive and affective states can in some circumstances be characterized from physiological signals, captured with commercially available biometric sensors [15]. In this project, we are investigating the use of a human's physiological response to a device stimuli (for example, an MP3 player's music or an audio podcast) in a device's control loop for implicit communication. In parallel, we examine the use of haptic stimuli as an immediate yet unintrusive channel for a device to communicate to a human that it has responded and performed some action as a result of his or her affective state, thereby closing the interaction feedback loop.

Our research, which considers standpoints of both signal classification and interaction design, helps define a model for a unique human-device interface that will be driven by implicit, low-attention communication. We posit that this new paradigm, if well designed, can be minimally invasive and will not require humans to be distracted by the peripheral device. To date, our work has followed two primary use cases: (a) finding one's place when one's listening to a content-rich media stream (e.g. an audio book or podcast) is interrupted; and (b) implicitly driving shifts of music style in realtime as a result of a user's sensed pleasure or unhappiness with the current selection.

In the first use case (audio stream bookmarking), we have implemented components of this Haptic-Affect Loop (HALO). We have developed a method of detecting orienting responses (using human galvanic skin response, or GSR) to external interruptions and automatically bookmarks the media such that the human can attend to the interruption, then resume listening from the point he or she was interrupted [14]. The feasibility of this approach has also been informally confirmed in a Wizard of Oz scenario in a noisy, uncontrolled outdoors environment [4]. Currently, we are exploring the secondary "browsing" stage of this interaction, with haptic annotations to indicate bookmark location and speed finding of the interrupted sequence - and thus completing the interaction feedback loop.

In the second use case (implicit switching of music), we began with an extensive participatory design process to investigate how such a system should work before actually implementing it [8]. With the confirmation that there is a potential for value within some user demographics and many design insights, we proceeded to explore methods to translate various physiological measurements into affective valence data during music-listening tasks. Of the many methods tried, the most effective to date employs Kalman filters.

5 Conclusions

In this paper, we have described three examples of haptic-affective design — a model for emotion sensing and display grounded in a haptically expressive and sensitive robot; the use of such a robot, combined with affect sensing, to drive an interactive loop that effectively mitigates anxiety; and implicit control that with just a GSR sensor can notice when you've been interrupted or want the system to change, do it, and let you know in an unintrusive way.

Together, these examples provide a broad survey of the design space in which haptics and affect sensing or display can work together in a complementary and powerful way. We look forward to increased research activity in this promising and exciting area.

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