A Tool to Study Affective Touch: Goals & Design of the Haptic Creature

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Abstract
Touch is an important part of many forms of emotional communication, but has been studied far less than visual and auditory expressions of affect. We are developing the *Haptic Creature* to investigate fundamentals of affective touch, and its applications in companionship and anxiety management. This small robot senses the world solely by being touched, and communicates its internal state via vibrotactile purring, stiffening its ears, and modulating its breathing. This paper outlines the motivation for its creation and design, and overviews the current version of its architecture and mechatronics.

Keywords
Haptic interface, affective touch, human-robot interaction, human-animal interaction, social touch.

ACM Classification Keywords
H.5.2 [User interfaces]: Haptic I/O; J.4 [Social and Behavioral Sciences]: Psychology, Sociology

Motivation and Approach
Affective touch can be defined as touch that communicates or evokes emotion; it is recognized as unique and highly influential among the senses in this regard [2, 6]. The larger purpose of the Haptic Creature project is to investigate the use of affective touch in the social interaction between human and robot: specifically to identify physical traits of affective

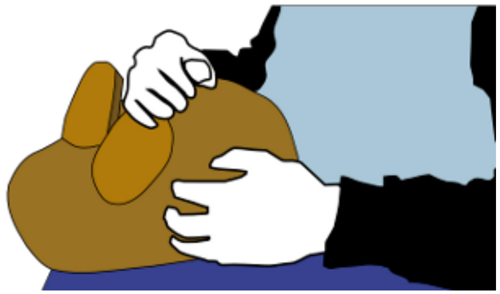

Figure 1: A human interacting through touch with a robot.

touching as well as applications in companionship and therapy. Our immediate goals along this path are the display and recognition of this form of touch by both human and machine, as well as the interactive touch dynamics that can develop between them.

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). The Haptic Creature interacts with the human entirely through touch by breathing, stiffening its ears, and purring in response to the user's touch. Our rationale for using an animal platform is to avoid factors in human-human social touching which would confound or overload our investigation – gender, familiarity, social status and culture – e.g. [3].

We plan to use the Haptic Creature in two ways. First, we will conduct a series of user studies targeted at revealing essential albeit situated traits of this form of touch, and mechatronic and computational needs for supporting them. What touch gestures do humans most naturally use to express specific emotions? What is required to *elicit* (form factor, surface textures, movements) and recognize them (sensing, modeling)? How are physically-expressed animal emotions recognized by humans, and what is mechatronically required to *express* them? Perhaps most interestingly, can we see how human gestures and robot-animal display influence one another: what happens when we close the loop? Can the robot's intervention alter the emotions that the human user is experiencing?

From that point, our second use for the Haptic Creature will be to examine interaction over a longer timeframe to investigate deeper relationships that may arise as a result. Can long-term affective touch between human and robot foster companionship? Can this form of interaction modulate mood or mitigate anxiety?

In the following, we provide some background and design criteria, the Haptic Creature's history and a look at its current physical and software implementation.

Background and High-Level Design Criteria

The Haptic Creature project draws from literature on social robotics, affect display, haptic psychophysics and human-animal interaction. A more complete review of these can be found in [11]; here, we simply note that while there have been several examples of emotionally communicative robots – e.g. MUTANT [4] and Kismet [1] – these have operated primarily or exclusively through visual and auditory display even when touching is involved: facial expression, posture, vocalizations. Paro [8] and Huggable [9] both use touch sensors and are responsive to touch. However, our goal was to study touch-based user interaction strategies in greater detail, and for this we needed a different platform.

Three high-level criteria have guided Haptic Creature design. (1) *A focus on touch interaction*. (2) *Organic and holistic behavior*. Sensing and all aspects of the

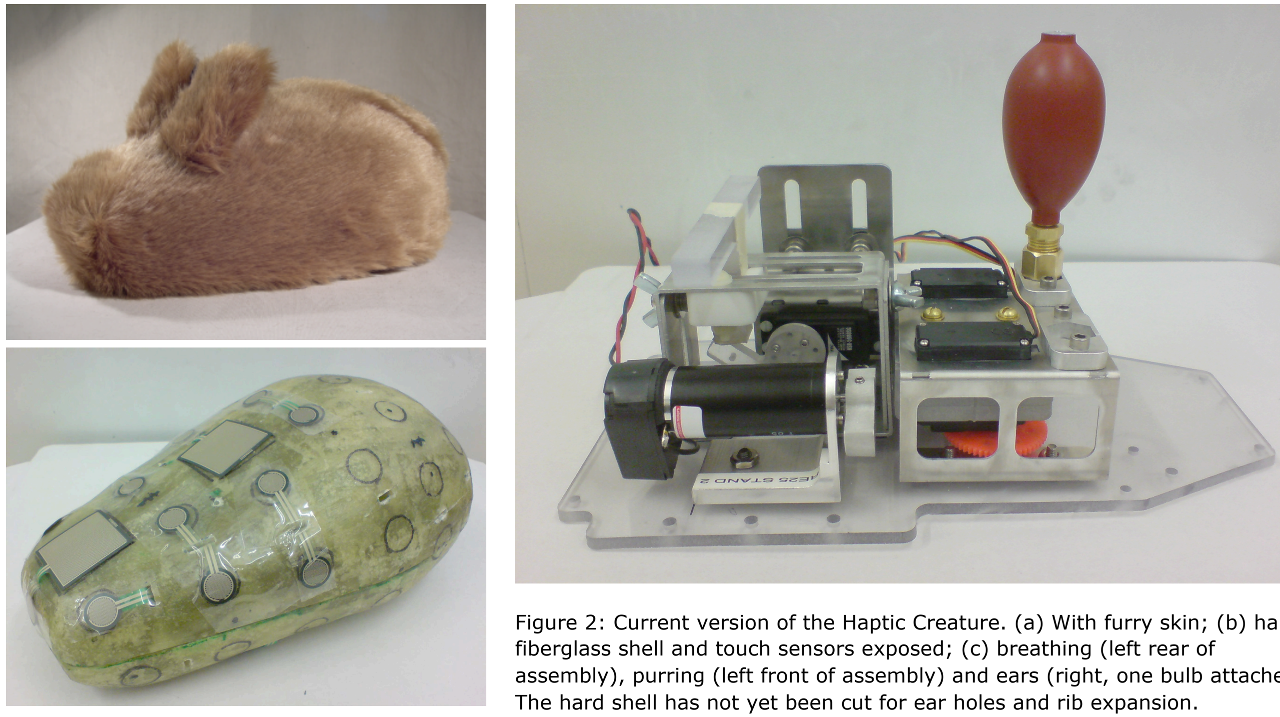

Figure 2: Current version of the Haptic Creature. (a) With furry skin; (b) hard fiberglass shell and touch sensors exposed; (c) breathing (left rear of assembly), purring (left front of assembly) and ears (right, one bulb attached). The hard shell has not yet been cut for ear holes and rib expansion.

affect display must work as a coordinated whole, rather than a disconnected “bag of tricks”. (3) *A low level of zoomorphism*. While we leverage familiar animal-like behavior, we *avoid* lifelike replication of a single existing animal. It would be difficult to fully achieve that goal, and the consequence of failing can cause rejection (e.g. Mori’s uncanny valley [7]).

The Creature’s History

The Creature’s first version was a Wizard of Oz (WOZ) prototype, with interactions managed by a team of human operators through pneumatics and vibrotactile displays and used in two user studies to date [5, 10]. This prototype allowed us to quickly explore our ideas and set parameters for an automated version.

These studies both found that most subjects were excited and engaged by even the simple WOZ prototype; but a small number found it disturbing or annoying. The emotion-to-display mappings tested in [10] were mostly confirmed, with agreement greatest for pet owners; the greatest challenge was to find the “expected” creature response to aggressive treatment like hitting or shaking, where a real animal’s response (escaping or fighting back) was not possible. Subtle emotional distinctions (“content” versus “happy” were

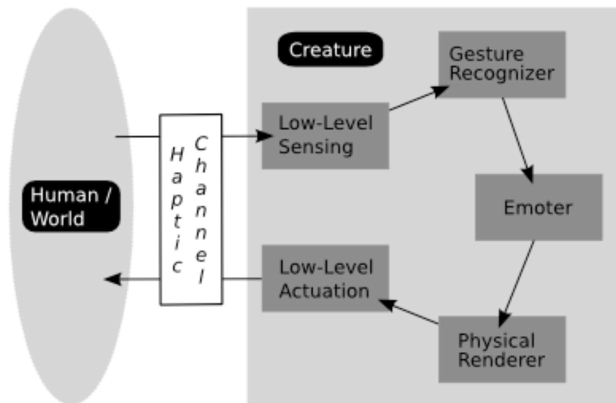

Figure 3: The Haptic Creature architecture. From [11].

difficult to render without a developed experience – true also of interactions with real animals. In [5], the ability of the WOZ version of the Creature to mitigate anxiety experienced in a stressful situation, as measured with biometrics and self-reports, was likewise found to be present and positive for many subjects but a negative for a small number. Again, we saw signs of a complex interaction with factors such as experience with small children and animals.

We have since moved through multiple semi-automated versions [11]; the present model is fully automated.

Emotion Model and Software Architecture

The current Haptic Creature's software architecture is illustrated in Figure 3, and described more fully in [11]. Its modular components are: (a) Low-level processing of the touch sensor signals. (b) Gesture recognizer: we construct an integrated but still mechanistic model of the physical data, classifying e.g. the region, speed, direction and pressure of a stroke or strike on the robot's surface. (c) Emoter: uses a combination of the recognized gesture, recent time history and its own model to formulate a response. (d) Physical renderer: translates the Emoter's ascertained state into a physical manifestation (e.g. ears gradually stiffened coupled with deepened and accelerated breathing). (e) Low-level actuation: implements (d)'s output.

The *Emoter's* current form is minimalistic: in a simple example, a soft, slow, correct-direction stroking can elicit a pleasured state – which could then take on a variety of manifestations, as dictated by the Physical Renderer. As the Creature's sophistication grows, the Emoter will take many forms depending on the purpose; modular design facilitates swapping of all components. In future more complex cases, with the help of machine learning techniques we anticipate that Creature will identify (through touch) and attempt to influence the human's current emotional state, e.g. by "coyly" causing the user to work hard to calm the Creature down; or play an interactive game in the same way we play small physical games with pets.

Creature Mechanics

The physical Creature, shown in Figure 2, consists of several passive and active components: fur and shell; mechanisms for breathing, ears, and purring; touch sensing and control electronics. Our low-level design criteria were quiet operation, lifelike response, robustness and low cost.

Passive Elements

The outer surface of the Haptic Creature is a soft synthetic fur chosen for its pleasing feel and rough approximation to animal fur. Beneath the fur we are investigating the application of a 0.25" layer of silicon rubber (Smooth-On Dragon Skin™), which provides a flesh-like quality to mitigate the rigid feel of the inner "turtle" shell. The shell, made from 0.375" fiberglass laminate, provides a rigid base for the touch sensors and houses the active components.

Breathing Mechanism

The breathing mechanism (visible in the assembly in *Figure 2*) consists of a Hitec HSR-5980SG servomotor that drives a T-shaped lever. The lever, constrained by a slotted guide, converts the servo's rotation to linear motion. The T-shaped lever in turn synchronously displaces the shell's "ribs" – an articulated section at its back – by a few millimeters. As the servo rotates, the T-lever moves up and down, thereby simulating the breathing motion by raising and lowering the shell. The speed of the mechanism varies with load: one complete cycle (~1.5cm) requires ~0.3 seconds when unloaded, and ~0.5 seconds with a hand placed on the Creature.

Ear Mechanism

The Creature has two ears whose stiffness can be individually controlled. Each has an inflatable rubber bulb (the ear, protruding through a hole in the shell but covered by fur) attached to a small outtake valve that controls its airflow. When the valve is fully closed, no air can be released so the ear feels stiff; as it is progressively opened, the bulb softens, with approximately 5 human-distinguishable levels of stiffness. Each valve is controlled via a separate Hitec HS322HD servomotor, which moves a few degrees between stiffness levels.

Purring Mechanism

Purring is achieved using a Maxon RE025 DC motor with an offset weight affixed to its shaft (see Figure 2c). The motor, chosen for its quiet and smooth, non-cogging motion and high dynamic range, produces a vibrotactile purring by modulating the speed at which the offset weight is rotated. The host software (Low-level Actuation block in Figure 3) can adjust its frequency at 25Hz. This allows for a wide range and smooth modulation of purring parameters: soft to hard, slow to fast, rhythmic to erratic. The major transmission point for purring is from the bottom of the creature to the human's lap; strong purring can also be felt with the hand on the robot's back and sides.

Touch Sensing

The robot has an array of 60 force sensing resistors (FSRs) strategically mounted atop its structural shell (Figure 2, shell view). These sensors, manufactured by Interlink Electronics, were chosen for availability and relative low cost. The majority are 0.5" circles, and seven are 1.5" squares. Preliminary investigations demonstrated a ~20% decrease in resolution when the larger sensors were bent to fit curved sections of the shell, so the smaller, circular FSRs are used there.

Sensing and Actuation Electronics

A Microchip PIC18F87J50 USB Demonstration Board, an inexpensive turnkey solution, handles all low-level control of sensing and actuation described in the previous sections. It provides USB for host-creature communication, analog-to-digital input for touch sensing, and pulse-width modulated output for motor control. The board is integrated with custom electronics that process the touch sensing and communicates with custom daughter boards for motor control. The microcontroller firmware has been specialized to meet our needs for communication and control processing.

Conclusion and Future Work

The main goal of the Haptic Creature project is to investigate the basis of affective touch in social situations; and longer-term, to explore applications in companionship and therapy where touch is known to be influential, sometimes in the form of human-animal interactions. In this paper, we have described a fully automated version of a platform with which we plan to conduct a series of user studies that will allow us to address these questions, and to refine our currently simplistic emotion model.

We view the human-robot interaction in a cyclical way. The human forms an impression of the creature's behavior, and the creature of the human's. Each *displays* its own response. These comprise the four linked blocks of the cycle. Our strategy is to first isolate, study and refine (as possible) each in turn, then connect them and study the combination. The outcome of this stage is a refined architecture and (probably) an extended physical specifications list. Subsequently, we will begin to explore applications in companionship and anxiety mitigation, through longitudinal exposure where richer patterns of interaction can be developed.

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