

Emotibot: An Interactive Tool for Multi-Sensory Affect Communication

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ABSTRACT

Effective emotional communication can have benefits in social interactions between a user and a robot. By developing a tool that can pivot easily between distinct emotional states in response to user presence or input, we have applied a multi-modal method for implementing affect communication in everyday interactions. Our interactive tool engages with users through three emotional avenues and has the potential for usage as an emotional or social support companion.

CCS CONCEPTS

• Human-centered computing → Human computer interaction (HCI).

KEYWORDS

Affective Haptics, Haptic Feedback, Audio Feedback, Socially Assistive Robotics, SAR

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1 INTRODUCTION

The existence of emotional expression within humans is vital to the quality of everyday interactions. Much of emotional expression is implicit, communicated using non-verbal cues and subtle gestures [5]. With dilated eyes, heavy breathing, and an elevated heart rate, fear is quickly communicated and other humans look for the source of fear that they might need to be immediately cautious of. An intentional smile can quickly communicate happiness, or that there is no threat nearby so that everyone can relax. Squinted eyes may quickly communicate a negative opinion of something that needs

to be changed or avoided [11]. Humans typically use these routes to efficiently communicate emotions.

We have created a multi-agent tool that mimics the implicit nature of human emotional expression and elicits user interactions. It can be kept in a commonly visited area, such as a desk, and used for emotional and social support. Using three modalities, including colored light, haptic feedback in the form of a heartbeat, and emotional audio, our tool shifts emotional state in response to user presence and interactions. Our tool's expressive capabilities improve its interaction quality and maximize valuable user engagement.

2 DESIGN

We decided that the tool, whether presented as an object or an animal, should maintain a generic appearance. However, the tool should present as some sort of living creature that elicits interaction from users. The tool should be visually appealing and inviting, but not indicative of any particular emotional state outside of the controlled affect communication modalities. Even a seemingly neutral feature like a persistent smile could influence user perceptions of the device's state. Initial design ideas, illustrated in Figure 1, mostly consisted of non-distinguishable zoomorphic beings, with little to no expression or features beyond a torso and eyes. These ideas also considered the need for ample space inside the plush to allow for hardware integration. From initial sketches, a crocheted plush in the style of amigurumi was identified as the platform for the proposed tool.

In the later steps of our design phase, we focused on establishing the exact features of the affect communication tool. Based on related works, we decided to adopt a multi-modal method for communicating emotions, in hopes that users would be more likely to correctly perceive portrayed emotions, and would more deeply enjoy the variety in engagement possibilities with the system [13]. We first decided to include audio feedback, as shifts in vocalization properties would likely be capable of demonstrating certain emotional states. In human interactions, shifts in tone, pitch, and inflection can indicate emotional shifts within conversation [4]. Our generalized platform is non-human and thus is not intended to respond like a human would in conversation. Instead, non-distinct sounds can be used for vocalizing responses and can take on the same dynamic parameters used in a human voice to express emotion. Another

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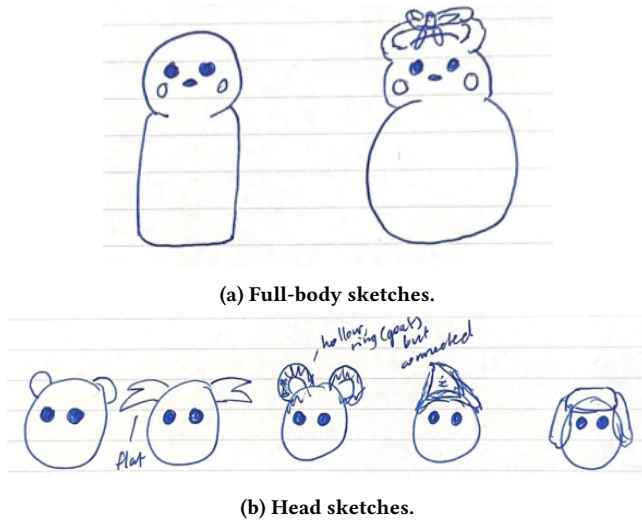


Figure 1: Preliminary sketches for the proposed affect communication system.

form of human-like emotion manifestation is a simulated heartbeat. Simulated heartbeats are often reminiscent of social touch in non-human interactions, which is applicable in a context that is intended to simulate emotional interaction [10]. Given common pre-conceived notions about emotion and heart rate correlations (e.g., fast heart rates indicating arousal) heartbeats can indicate shifts to familiar states such as anxiety or happiness. By corresponding the simulated heart rate with the tool's emotional state, we planned to integrate this second modality into the overall emotional communication methodology. Colors are also commonly associated with particular emotions [9]. Based on this, we decided to include a visual aspect in our affect communication that dynamically changes a portrayed color based on shifts in prompted emotional state, in the form of glowing colored cheeks. With these avenues identified, a question remained as to what would prompt shifts in this portrayed emotional state.

We decided to add a second component to our system design to serve as a "base" object, adjacent to the system. This base would be used to delegate emotional shifts to the crocheted characters, based on perceived user prompts or toggles. User presence would be evaluated using proximity sensing, and the plush would respond accordingly to this presence. Due to the need for visibility of the user, the base needs to be visible and coupled with the plush, but should match the theme of the tool and remain inconspicuous with respect to its sensing purposes. Thus, the base should be some crocheted or otherwise soft object that will correspond with the appearance of the main figure. Additional sketches that incorporate this base object are illustrated in Figure 2.

Ultimately, the established design of the system (see Figure 3) consisted of two mushroom-like creatures, accompanied by a cottage-like house to serve as a base object. Creating a non-zoomorphic design leads to a more objective user experience and avoids user preconceptions tied to specific animals, such as the typical expectation of a puppy being naturally happy. Additionally, using a house as the base object gives a sense of privacy to its contents, which will

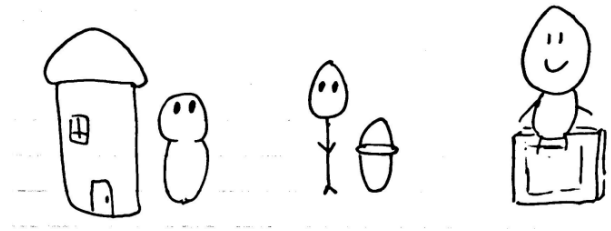


Figure 2: Sketches of the system, including possible "base" objects.

potentially discourage users from inspecting it further and taking away from the illusion of the creatures' environment [2].

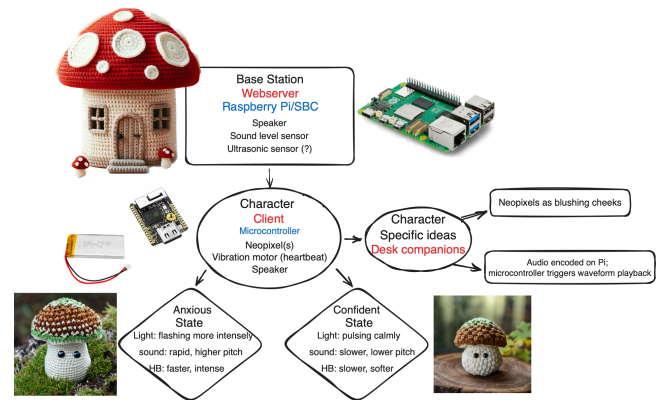


Figure 3: An architectural diagram of the proposed system, including reference photos for creature and house appearances and descriptions of potential technical functionality.

3 IMPLEMENTATION

After determining the expected qualities and interactions of the creature, we began developing a tangible prototype. During the initial creature design phase, we created one interactive creature as a proof of concept. In order to offer more opportunities for a user to interact with a variety of affective states, we decided to implement a system with two or more interactive creatures that complement each other, as opposed to a solitary creature. These creatures will often have contrasting emotional responses to users that correspond to particular predefined personalities and interaction patterns. During the implementation of support for contextual behaviors, predefined emotional states were also established: happy, sad, and anxious. Modalities for affect communication will be configured to adopt one of these three states when prompted.

We established a multi-agent network of two toy-like creatures and one house-like base object, behaving in the manner of two clients and a server. The two creatures each contain an ESP32 microcontroller, an Adafruit DRV2605 haptic driver breakout board, and an Adafruit mini vibration motor, as well as a NeoPixel strand and wireless Bluetooth speaker. Each creature is powered by a lithium polymer battery. The base object contains a Raspberry Pi 3, which is currently powered using a 5V mini USB cable, as well as an ultrasonic sensor. The contained sensor is used to detect human



Figure 4: The completed system, composed of two creatures and a base object.

presence, which activates responses in each creature dependent on its distinct personality. The Raspberry Pi communicates with each creature through a Bluetooth connection to each ESP32. Bluetooth communication occurs when the ultrasonic sensor detects a user, and such detection is handled accordingly in each creature’s micro-controller software. This client-side handling allows for differing responses to the same prompt of user presence, in alignment with the creatures’ contrasting personalities.

3.1 Audio Feedback

In developing the audio feedback portion of our system, a GitHub repository for generating “animalese” was identified as an appropriate source of generated audio for our emotional states[3]. “Animalese,” a nonsensical style of verbal communication utilized in Nintendo’s Animal Crossing video game series, consists of syllables mimicking the prosody of human speech without forming meaningful words; this is ideal for our creature to communicate emotionally without the need for dialogue management. This generation was performed using a single Python script, and various audio files were saved and hand-selected based on parameters guided by existing audio research [1, 8]. Lower pitches, with longer intervals between each sound, were utilized to convey sadness. For happiness, moderate pitches were played at more frequent, yet still moderate intervals. In contrast, for the anxious state, high pitches were played with very short intervals between each sound. These audio states were performed in tandem with the other output states.

3.2 Haptic Heartbeat

To create a vibration that is emotional and engaging, we began by aiming to simulate a simple heartbeat waveform. We used an Adafruit vibrating mini motor disc, a small but effective ERM motor, to create our vibrotactile heartbeat. The motor was programmed using the Arduino IDE. This code was written to an ESP32 development board, which interfaced with the motor via an Adafruit DRV2605 Haptic Controller Breakout. In this program, a sequence of vibrations and brief delays are strung together in a way that mimics a typical human or animal heartbeat. In order to simulate specific emotional states, the heart rate of the simulated heartbeat is altered to match commonly perceived relationships between heart

rate and emotion. An anxious state is portrayed by a fast heart rate, which we define as over 100 beats per minute (BPM), a happy state is portrayed by a normal heart rate, and a sad state is portrayed by a slowed heart rate (under 70 BPM). Typical and atypical ranges for human heart rates were used as references for these correlations to ensure users can relate to the portrayed states [7].

3.3 Visual Feedback

In alignment with commonly identified perceptions about color-emotion associations, we established three emotionally correlated cheek colors for each creature. A green cheek color indicates a happy and relaxed state. A blue cheek color indicates a sad state. A red cheek color indicates a fearful and anxious state. These correlations are supported by previous research conducted in the United States on the relationship between color and emotion [6, 9].

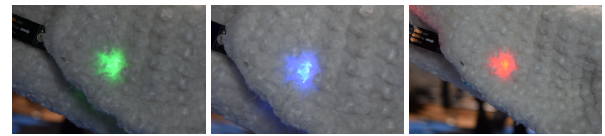


Figure 5: Green, blue, and red NeoPixels underneath the white crocheted fabric used in the creatures.

The glowing cheek effect created by a strand of Adafruit NeoPixels also includes brightness growths and decays. The speed of this pulsing changes depending on the emotional state. An anxious state utilizes a rapid pulsing sequence, a sad state utilizes a very slow pulsing sequence, and a happy state maintains a medium speed of pulsing.

4 USER INTERACTION

The affective communication tool was designed for creating engaging user interactions and can be useful for both entertainment and support purposes alike. Given the size of the resulting system, its primary context was envisioned as a “desk pet” environment. Similar domesticated robots have been studied, with user engagement being seemingly dependent on user preferences and long-term interest [12].

Unlike other smart desk pets, such as Vector [12], our system cannot move on its own, but rather is statically situated in the user’s preferred setting. Additionally, given that the system’s primary prompt is human presence, the base object should remain situated in one area and its connected creatures should remain nearby. The two creatures within our system have different personalities, reacting distinctly in both the detected presence and absence of the user. An illustration of these behaviors is provided in Figure 6. These unique contextual behaviors allow for a more diverse affective experience for the user, and prompt further interactions beyond approaching the creatures (i.e. wanting to comfort a sad or anxious creature).

In the context of a user interaction, the tall creature is initially sad because, to its knowledge, there are no humans around to interact with it. This is portrayed by blue, slow-pulsing cheeks, a slowed heartbeat, and low-pitched sounds. The short creature is initially happy to be alone, which is communicated by green cheeks, a mid-range heart rate, and slightly high-pitched sounds. The interaction

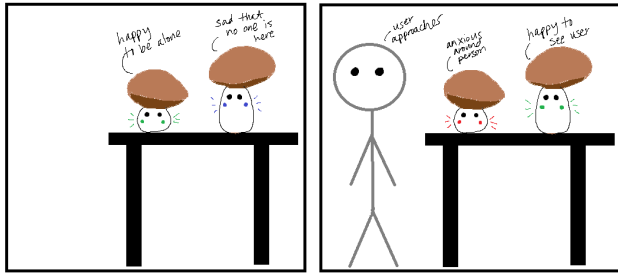


Figure 6: A sketched scenario diagram for the system's contextual behaviors.

styles that are enacted before a user is "present" are in place to show functionality to users outside of the range of the ultrasonic sensor. In other words, emotional states portrayed during a lack of user presence apply to scenarios when users are distant. When a user approaches the creatures, they immediately respond with a change in emotional state, in a way that continues to reflect their distinct personalities. The tall one becomes happy to see the user. Its cheeks fade from blue to green, its heart rate increases, and it makes slightly higher-pitched sounds. The short creature becomes scared to see someone new. Its cheeks fade from green to red, its heart rate increases, and it plays much higher-pitched sounds. The user can watch the creatures closely to try to decipher what they are and how they are feeling. The creatures can be picked up and held, spoken to, or simply carefully observed. When a user ends the interaction by walking away from the creatures, they return to their initial state. In this case, the tall creature is sad to see the user go, and the short creature is happy to be alone once again.

5 FUTURE WORK

We are working toward developing more sophisticated forms of response and interaction, based on improvements to sensing capabilities. With current configurations, the system is static within its two distinct states (with user presence and without user presence), which only allows for minimal variety in interaction. We plan on creating additional emotional states for the creatures to portray, and defining what parameters may allow for shifts to these states. To appropriately incorporate new response mechanisms, we must also incorporate new methods for creating awareness within the tool. Other sensing methods, such as touch sensing and vocal recognition, may allow for more adequate detection of the user's state and interactions. We are currently working on implementing an inertial measurement unit (IMU) to detect when the creature is picked up by a user so that the creature is capable of responding to specific user actions, rather than solely responding to presence. This addition will also remove reliance on proximity to the base object for the creatures to accurately shift their emotional state.

We are also working toward sensing and responding to specific user emotions, rather than only responding to user presence. Currently, the system utilizes only an ultrasonic sensor within the base object for sensing, which limits its ability to respond personally to user emotions or states. With a method for quickly collecting and analyzing biometric data to infer emotional state, our system could respond adequately to a user's emotion without the need for direct interaction. By communicating the user's current emotion to our

affect production system, we could enable our tool to appear more reactive.

Such a reactive tool would be useful in social capacities, including emotional and social support. By understanding the user's current emotional state, a robot could respond in an appropriate way to assist a user toward a more desirable emotional state. For instance, if the robot can tell that a user is sad, it could attempt to communicate a happy state to cheer up the sad user. Even in the case that a user is in a neutral emotional state, the tool could serve as a socially interactive entity situated within an everyday routine, such as working at a desk. The affect communication tool presented in this paper would be perfect to integrate into such a system to communicate any necessary emotion.

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