HexTouch: Affective Robot Touch for Complementary Interactions to Companion Agents in Virtual Reality

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ABSTRACT

There is a growing need for social interaction in Virtual Reality (VR). Current social VR applications enable human-agent or interpersonal communication, usually by means of visual and audio cues. Touch, which is also an essential method for affective communication, has not received as much attention. To address this, we introduce HexTouch, a forearm-mounted robot that performs touch behaviors in sync with the behaviors of a companion agent, to complement visual and auditory feedback in virtual reality. The robot consists of four robotic tactors driven by servo motors, which render specific tactile patterns to communicate primary emotions (fear, happiness, disgust, anger, and sympathy). We demonstrate HexTouch through a VR game with physical-virtual agent interactions that facilitate the player-companion relationship and increase the immersion of the VR experience. The player will receive affective haptic cues while collaborating with the agent to complete the mission in the game. The multisensory system for affective communication also has the potential to enhance sociality in the virtual world.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; **Virtual reality**.

KEYWORDS

Expressive Robotics; Haptics; Virtual Reality; Wearable; Physical Contact; Emotion Communication

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1 INTRODUCTION

With the rise of VR application, creating haptic feedback becomes increasingly important to improve the immersion. Previous studies have attempted to let users feel the shape, stiffness, texture, and even the weight of the virtual objects [1, 4] to create the simultaneous sensing of the objects being manipulated in VR scenes. However, to create an immersive experience that is similar to the real world, only simulating physical properties is not enough. While the VR games are criticized for being isolating because they shift the player's perception from the real world to the virtual world [7], there is a greater needed to explore the sociality (association tendency) of VR worlds.

One method to improve sociality is designing compelling companion agents in VR games. Companion agent is a persistent non-player character (NPC) that accompanies a player throughout the game. It can introduce the game rules, showing the direction, and providing notifications as a "sidekick", or perform as an "ally" that fights alongside the player. Playing video games with an interactive companion has great potential to increase game enjoyment [3] and decrease the loneliness of game experiences [7]. To create a compelling companion agent, emotion, awareness, and relation to the player are crucial attributes [3]. For a companion agent in an immersive VR game, a multisensory system for the affective interactions has great potential to improve those attributes. In the context of such modalities, we focus on touch. While touch is the primary nonverbal means of communication in the natural world, tactile feedback can be relevant and less distracting in environments that already have rich visual and audio data, like in many VR game scenes [6]. Improving the tactile feedback for VR games can greatly increase the immersion and embeddedness [6] of a player.

Hereby, we explore affective tactile cues to complement visual and auditory channels to enrich the companion agent interactions in VR. While previous studies have explored vision and audio channels for emotional expression in human-robot interaction [5], touch has not received as much attention. The psychology study conducted by Hertenstein et al. showed that distinct emotions can be communicated through specific tactile behaviors between individuals [2]. Zhou et al.'s study [8] showed how one of the human touch effectors may be replaceable with a robotic tactor interface as well. The preliminary results indicate that humans can indeed decode distinct emotions (fear, happiness, disgust, anger, and sympathy) solely through robotic touch. Using this prior art, we create HexTouch, a forearm-worn version of the tactor robot that can render touch patterns in sync with the behavior of the companion agent.

2 SYSTEM DESIGN

HexTouch is a wearable haptic device that consists of four robotic tactors driven by servo motors, controlled by an Arduino Nano (Fig. 1(d)). It is lightweight (340g) and is fabricated with skin-friendly basswood (Fig. 1(a)). The base of the device fits the length from the wrist to the middle part of the forearm (7 x 4.7 x 1.2 inches). It is attached to the forearm using velcro tape (Fig. 1(a)). To communicate the primary emotions, specific tactile patterns (Fig. 2) were

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programmed based on Zhou et al.'s study [8]. For each emotion, the tactile behaviors were decided (Fig. 2) from the most frequently used tactile behaviors for target emotion documented in Hertenstein et al.'s study [2]. For instance, humans were more likely to use "squeezing and trembling" to express fear, "shaking and swinging" for happiness, etc. HexTouch also provides haptic feedback for other interactions in the game, such as notification, directional cues by gentle tapping, squeezing to show making efforts (Fig. 2). It also performs some social gestures like bracing (Fig. 2).

Our VR game is built for Oculus Quest, developed in Unity 3D. We designed sound effects, facial expressions, and body movements for the virtual agent's affective interaction (Fig. 1(b)). For HexTouch's tactor motions, we use Oculus Link to transmit data of gameplay to Unity3D, which communicates with Nano through serial (Fig. 1(c)).

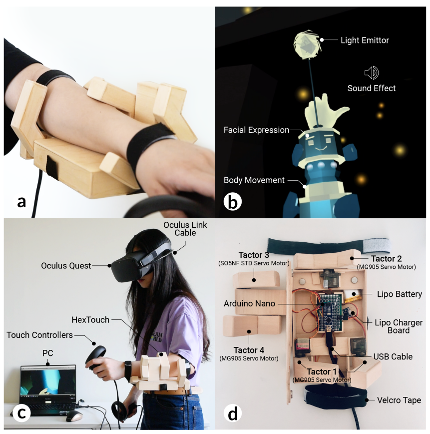

Figure 1: System Overview (a) HexTouch, a wearable haptic robot (b) The companion agent in the VR game (c) setting of the demo (d) The internal view of HexTouch

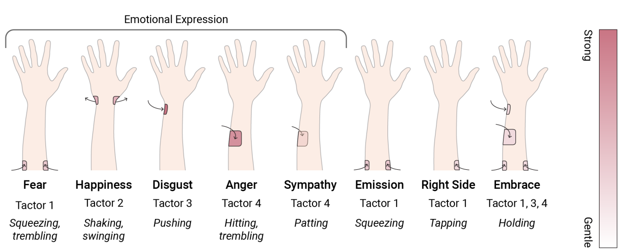

Figure 2: Tactile patterns for each interaction

3 DEMONSTRATION

We developed a VR game with a companion agent to demonstrate HexTouch. In the game, player will follow the guidance of the agent and collaborate with it to complete the mission. Players can test the HexTouch and experience the multisensory affective interaction of the companion agent simply by putting on the Oculus Quest and HexTouch device. HexTouch can be calibrated with a software toolkit in order to fit different arm sizes. We held a preliminary user test with four players. They remarked that the "tactile feedback indeed made the agent more vivid and being-like," and the "touch patterns were easy to understand and matched well with the visual and audio feedback." Another user mentioned that "the touch sensation made them pay more attention to the agent's feelings and arouse their empathy." We also found that the players were more likely to touch the agent in the virtual world while receiving the robotic touch. For instance, three of the players tried to pat the agent when it showed fear because of seeing a virtual spider.

4 CONCLUSIONS AND FUTURE WORK

We propose HexTouch, a wearable haptic robot that renders affective touch clues through robotic tactors, including specific touch patterns that communicate primary emotions. Using HexTouch, we created a multisensory interaction system and used it for companion agents in VR. For our future studies, we plan to evaluate the complementary effect of the affective touch. We will recruit participants to test our VR demo without HexTouch first and ask them to interact with the companion agent again while wearing the haptic device to see how can the robotic touch influence their perception of the affective interaction. We hypothesize that the tactile cues can make the companion agent more compelling. Such tactile interactions can complement the visual and auditory feedback for the interactions and enrich the emotional expression of an agent, which also has the potential to enhance the sociality in VR.

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