HexTouch: A Wearable Haptic Robot for Complementary Interactions to Companion Agents in Virtual Reality

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Figure 1: (a) Play VR games with HexTouch (b-f) HexTouch is communicating emotions via tactile patterns in sync with the agent's behaviors (g) HexTouch can physically hug the player (h, i) HexTouch can provide notifications and directional cues

ABSTRACT

We propose a forearm-mounted robot that performs complementary touches in relation to the behaviors of a companion agent in virtual reality (VR). The robot consists of a series of tactors driven by servo motors that render specific tactile patterns to communicate primary emotions (fear, happiness, disgust, anger, and sympathy) and other notification cues. We showcase this through a VR game with physical-virtual agent interactions that facilitate the player-companion relationship and increase user immersion in specific scenarios. The player collaborates with the agent to complete a mission while receiving affective haptic cues with the potential to enhance sociality in the virtual world.

CCS CONCEPTS

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

KEYWORDS

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

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1 INTRODUCTION

Wearable haptic device for VR is a significant trend in human-computer interaction. Previous studies have attempted to simulate the physical properties in VR scenes that let users feel the shape, stiffness, texture, and even the weight of the virtual objects [Choi et al. 2017; Gu et al. 2016]. However, the haptic channel can also communicate affective information, especially through the physical touch [Hertenstein et al. 2006], which has not been well studied in the VR context. VR games are usually criticized as isolating because they shift a player's perception from the real environment to the virtual world [Liszio et al. 2017]. Thus, there is a greater need to explore the sociality (association tendency) of VR worlds.

In games, a companion agent is a persistent non-player character (NPC) that accompanies a player on missions. Such agents can improve the sociality of VR games [Emmerich et al. 2018]. For example, the agent can introduce game rules, show directions, provide notifications like a "sidekick," or fight alongside the player like an "ally". Playing video games with such an interactive companion can increase game enjoyment [Emmerich et al. 2018] and decrease the loneliness of game experiences [Liszio et al. 2017]. To create a compelling companion agent, emotion, awareness, and relation to the player are crucial attributes [Emmerich et al. 2018]. We specifically focus on touch because it 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 [Jones 2008]. Improving the affective tactile feedback for VR games has great potential to increase the immersion and embeddedness of a player.

To address this, we explore tactile cues that complement visual and auditory channels to enrich the interactions of a companion agent in VR. Hertenstein et al. conducted a study of interpersonal touch that showed distinct emotions communicated through specific tactile behaviors between individuals [Hertenstein et al. 2006].

Our previous study [Zhou and Sareen 2020] showed how one of the human touch effectors may be replaceable with a robotic tactor interface as well. Preliminary results indicated that humans can indeed decode distinct emotions (fear, happiness, disgust, anger, and sympathy) solely through robotic touch. Based on this, HexTouch is a forearm-worn version of the tactor interface that can perform touch in specific patterns corresponding to the behavior of the companion agent.

2 SYSTEM DESIGN

HexTouch is fabricated with lightweight (14 ounces) and skin-friendly basswood(Fig. 2(b)). The base of the device fits the length from the wrist to the middle of the forearm (7 x 4.7 x 1.2 inches). It is attached to the forearm using velcro tape (Fig. 2(b)) and consists of four robotic tactors driven by servo motors that are controlled by an Arduino Nano. To explore how different textures may influence people's interpretation of the affective interaction, we also designed furry clothes (Fig. 2(c)) for the robot. Specific tactile patterns were programmed based on Zhou et al.'s study [Zhou and Sareen 2020]. We use line graphs to visualize touch behaviors of normal forces applied to the forearm(fig. 2(a)). For each emotion, the tactile behaviors were decided (Fig. 1(b-f)) from the most frequent types of touch for target emotion documented in Hertenstein et al.'s study [Hertenstein et al. 2006]. For instance, fear was usually associated with squeezing and trembling, and sympathy was associated with patting. HexTouch also provides haptic feedback for other interactions in the game, such as notification or directional cues by gentle tapping (Fig. 1(h)), squeezing to show making efforts to generate power (Fig. 1(i)). It also performs some social gestures like bracing a forearm for comfort (Fig. 1(g)).

Our VR game is built for Oculus Quest and was developed in Unity 3D. In the VR game, we designed sound effects, facial expressions, and body movements for the companion agent. We use Oculus Link to transmit data of gameplay to Unity3D, which communicates with Nano through serial (Fig. 2(d)) to control HexTouch's tactile behaviors.

3 DEMO

We will demo our VR game in the exhibition. Players can test the HexTouch with two different textures simply by putting on the Oculus Quest and HexTouch device. They will experience the haptic touches relating to the agent's behaviors in the game. 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 for each emotion 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." 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.

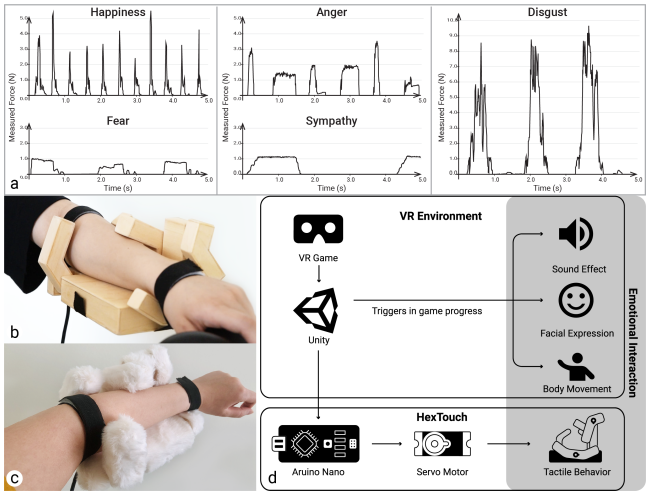

Figure 2: (a) Measured normal force on the forearm for each emotion (b) HexTouch, a wearable haptic robot(c) HexTouch in furry clothes (d) System overview

4 CONCLUSIONS AND FUTURE WORK

In this paper, we present HexTouch, a wearable haptic robot that touches the player to complement the visual and auditory feedback of the emotive game companion in VR. Such tactile stimulations can enrich the expressiveness of the virtual agent and have the potential to increase the sociality of the gaming experience in VR. In our future work, we will work on designing more agents in different forms and exploring communicating a wider range of emotions with robotic touch.

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