Touch the virtual reality: using the Leap Motion controller for hand tracking and wearable tactile devices for immersive haptic rendering*

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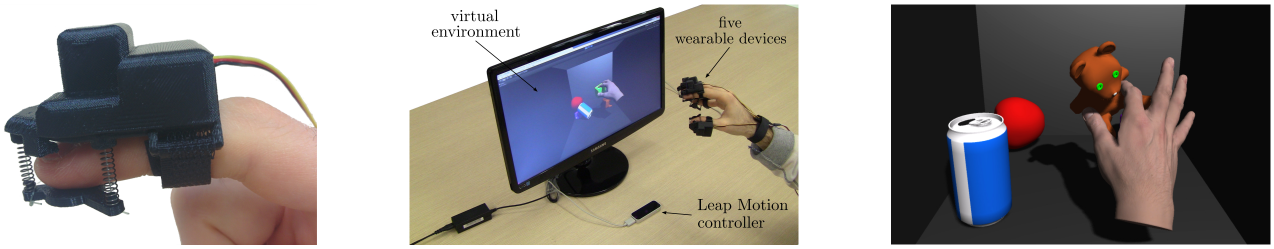

(a) (b) (c)

Figure 1: *Immersive tactile interaction in a virtual environment. User's fingertips are tracked using a Leap Motion controller (b) while five wearable tactile interfaces (a) provide the human operator with the compelling illusion of touching a virtual object (c).*

1 Introduction

The complexity of the world around us is creating a demand for novel interfaces that will simplify and enhance the way we interact with the environment. The recently unveiled Android Wear operating system addresses this demand by providing a modern system for all those companies that are now developing wearable devices, also known as "wearables". Wearability of robotic devices will enable novel forms of human intention recognition through haptic signals and novel forms of communication between humans and robots. Specifically, wearable haptics will enable devices to communicate with humans during their interaction with the environment they share. Wearable haptic technology have been introduced in our everyday life by Sony. In 1997 its DualShock controller for PlayStation revolutionized the gaming industry by introducing a simple but effective vibrotactile feedback. More recently, Apple unveiled the Apple Watch, which embeds a linear actuator that can make the watch vibrate. It is used whenever the wearer receives an alert or notification, or to communicate with other Apple Watch owners.

However, the force feedback provided by these popular devices is still limited to vibrations, reducing the possibility of simulating any rich contact interaction. Towards a more realistic feeling of interacting with virtual and remote objects, researchers focused on glove-type haptic displays, such as the CyberGrasp, which provide force sensations to all the fingers of the hand simultaneously. However, although they provide a compelling force feedback, these displays are still complex and *very* expensive. For this reason it becomes crucial to find a trade-off between a realistic feeling of touch and cost/wearability of the system. In this respect, we found *tactile technologies* very promising. Tactile devices are haptic interfaces able to provide tactile force feedback only. This property makes possible to dramatically simplify their form factor and, at the same time, provide a compelling and realistic feeling of touching virtual objects [Pacchierotti et al. 2014].

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2 Contribution

We present a novel haptic system for immersive virtual reality interaction. It consists of a Leap Motion controller and five wearable tactile devices. The Leap Motion controller is a small USB peripheral device that uses two monochromatic IR cameras and three infrared LEDs to track the position of the fingertips in 3-D space. It observes a hemispherical area up to a distance of 1 m with an accuracy up to 0.01 mm. Each wearable tactile device is composed of two platforms: one placed on the nail side of the finger and one in contact with the finger pulp, connected by three cables (Fig. 1a). One small servomotor controls the length of the cables, thus being able move the platform towards or away from the fingertip. As a consequence, a normal force can be displayed at the user's fingertip. Each device is connected to a wrist bracelet, providing power and wireless connection to an external computer. With respect to our previous haptic virtual reality system [Meli et al. 2014], we greatly improved the form-factor of the wearable devices employed. This allows us to easily track up to five wearable tactile devices (Fig. 1b).

We validated our immersive system in a virtual reality scenario (see Fig. 1c and the video at http://y2u.be/4OmDvWFCJXM). Users were asked to wear five tactile devices on one hand and interact with different virtual objects. The hand pose was tracked using the Leap Motion controller. A virtual hand mimicked the user's hand pose. Every time the hand came in contact with a virtual object, the tactile devices applied a suitable amount of force to the users' fingertips, providing them with the compelling sensation of *touching* the virtual environment.

The proposed tactile system is extremely wearable, effective, inexpensive, and completely wireless. There are in fact no workspace restrictions apart from the ones related to the gesture recognition technique.

References

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