REVEL: Tactile Feedback Technology for Augmented Reality

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1. REVEL: Augmented Reality Tactile Display

Augmented Reality has recently emerged as one of the key application areas of interactive computer graphics and is rapidly expanding from research laboratories into everyday use. The fundamental premise of AR is to enable us to interact with virtual objects immediately and directly, seeing, feeling and manipulating them just as we do physical objects. Most AR applications, however, provide only visual augmentation of the real world and do not provide the means to let the user *feel* tactile, physical properties of virtual objects or to enhance the physical world with computer-generated tactile textures. The absence of tactile feedback does not allow us to take advantage of the powerful mechanisms of the human sense of touch and diminishes the quality of the experience.

REVEL [Bau and Poupyrev 2012] is a new augmented reality (AR) tactile technology. Using a device worn by the user, REVEL changes the tactile feeling of real objects by augmenting them with virtual tactile textures. Unlike previous attempts to enhance AR environments with haptics, we neither physically actuate objects or use any force- or tactile-feedback devices, nor require users to wear tactile gloves or other apparatus on their hands. Instead, we employ the principle of *reverse-electrovibration* where we inject a weak electrical signal anywhere on the user body creating an oscillating electrical field around the user's fingers. When sliding his or her fingers on a surface of the object, the user perceives highly distinctive tactile textures augmenting the physical object. By tracking the objects and location of the touch, we associate dynamic tactile sensations to the interaction context. REVEL is built upon our previous work on designing electrovibration-based tactile feedback for touch surfaces [Bau, et al. 2010]. REVEL expands tactile interfaces based on electrovibration beyond touch surfaces and brings them into the real world, and can be used to enhance AR interaction with dynamic and unobtrusive tactile feedback.

2. REVEL System Design

Figure 3 presents the design of an AR tactile display based on reverse electrovibration using REVEL. A *tactile signal generator* (Figure 2) worn by the user communicates with an *AR display* and a *context-sensing* system. This, for example, can be an overhead projector and computer vision tracking system that recognizes when the user is touching a *physical object* augmented with virtual content. The context-sensing system triggers the signal generator to inject a *tactile AC signal* into the user's body. Thus, when the user is sliding fingers on the surface of a physical object, he or she would feel virtual tactile textures when necessary, e.g., when the user's fingers touch *virtual content* overlaid on the physical object. Although the physical object is completely passive, there are two crucial requirements that must be met for REVEL system to function. First, the surface of the object or the parts of it that are touched by the user must be conductive and covered with a very thin layer of insulator (Figure 1). Second, the conductive surface of the object and tactile signal generator should share a common electrical ground (Figure 3 Z and Z').

The REVEL tactile technology allows designing new and exciting AR experiences that are either difficult or impossible to create with existing tactile AR technologies, including interactive surfaces, video see-through AR (Figure 1) and tangible AR interfaces.

Figure 1: *The user feels virtual tactile textures on a real object while observing them on an AR display. Note, that the object is* not *instrumented with any tactile actuation apparatus.*

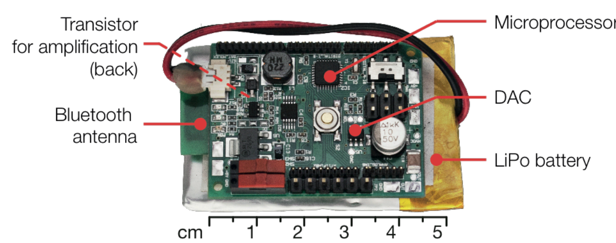

Figure 2: *REVEL signal generator board.*

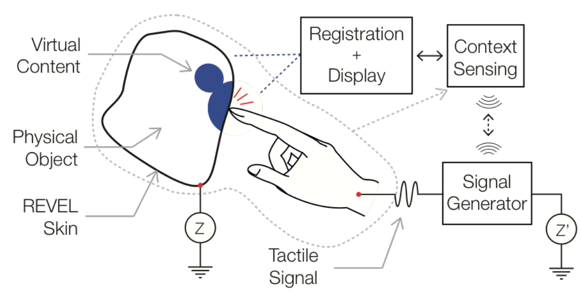

Figure 3: *REVEL tactile AR system diagram.*

References

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