Sensory Property in Fusion of Visual/Haptic Cues by Using Mixed Reality

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Abstract

When we recognize objects, multiple sensory information (e.g., visual, auditory, and haptic) is used with fusion. For example, both eyes and hands provide relevant information about an object’s shape. We investigate how sensory stimuli interact with each other. For that purpose, we developed a system that gives haptic/visual sensory fusion using a mixed reality technique. Our experiments show that the haptic stimulus seems to be affected by visual stimulus when a discrepancy exists between vision and haptic stimuli.

1. Introduction

When making a purchase online, we are sometimes disappointed by a product whose display on TV originally impressed us because its actual scale and material differ from our image. This case indicates that we use integrated multiple sensory cues that are not only visual but also audio and haptic to extract the properties of objects. However, how multiple sensory cues are fused by interaction with each other has not been well examined.

We have developed a system that can independently control the sensibility parameters of visual and haptic cues to study the effect of visual and haptic cues on sensory properties. A conceptual overview of this idea is illustrated in Figure 1.

2. Fusion of Visual/Haptic Cues Using Mixed Reality

It is common knowledge that we mainly rely on visual cues to estimate environmental properties. As a result, some researches report that haptic cues are affected by visual cues [1] [2]. Several studies have addressed this issue in the real world [3] [4]. In these researches, however, since subjects could not watch an object, they had to imagine that they are grasping what they are watching. By focusing on such inconvenience we have developed a system that provides various impressions of an observed object by showing different visual information from the actual shape and material using a mixed reality (MR) technique.

Figure 1: Fusing Visual/Haptic Senses Using Mixed Reality

This display system might create a new style of product design to reduce operation processes. For example, in ordinary product design, when a designer wants to evaluate different impressions caused by subtle changes of the surface material, many similar preproduction samples must be generated that correspond to each change. However, design variations are usually limited because they are too expensive. On the other hand, using our proposed system, evaluation is possible by superimposing computer graphics (CG) textures of various appearances onto a design mock-up that solves not only cost problems but also limitations of trial design variations.

To realize such a design support system, it is important to investigate how visual and haptic sensory sources are fused and affect each other. As a procedure to analyze sensory properties, we focus on the sharpness of a cube’s edge, which is strongly affected by both visual and haptic senses. Below we introduce an experiment that evaluates the sensation of sharpness by overlapping various visual appearances onto real 3D cubes using our system.
3. Subjective Evaluation of Sharpness

We conducted an experimental survey to investigate whether an edge is perceived sharper than its actual curvature by overlapping a sharper appearance on the surface. Figure 2 shows an overview of this experiment.

Figure 2: Overview of Subjective Evaluation of Sharpness Sensation

3.1 Experimental Environment

We prepared three cubes with 10 cm sides to control haptic stimuli. One cube has 12 edges of curvature radius from 0.0 to 1.1 mm, one has edges from 1.2 to 2.3 mm, and another has edges from 2.4 to 3.5 mm. To provide higher realism to subjects, we used a high resolution head mounted display (HMD) that has SXGA (1280 × 1024 pixels) resolution. It is possible to generate various CG appearances of the cube by controlling the curvature radii of the CG edges. By considering different thresholds of visual and haptic information, we quantize the scale of the curvature radii into seven identical parts: 0.2, 0.6, 1.0, 1.4, 1.8, 2.2, and 2.6 mm. Two are set as a standard for the matching test described below.

Twelve male subjects in their 20’s evaluated sharpness sensations by touching a CG overlapped cube that contained a discrepancy between vision and haptic stimuli. To solve the CG appearance problem, which involves overlapping of the subject’s hand in MR scenes, subject hands were extracted by calculating Mahalanobis distance based on skin color.

3.2 Procedure of Subjective Evaluation

First, as a reference of the matching process, subjects were presented a standard stimulus in three ways: haptic, visual, and both. Then subjects were required to determine a corresponding stimulus by only using haptic, only vision, and both haptic and vision together. On all trials, the subjects were permitted to take as much time as needed.

3.3 Results

Results are illustrated in Figure 3. The bottommost dashed line is mean matching response when standard stimuli are presented only by haptic, the top solid line is only using vision, and the mid chain line is using haptic and vision together.

As shown with a red circle in Figure 3, when subjects touch an object that has a 1.4 mm haptic curvature radius and a 2.2 mm vision one, they sense it as 1.8±0.169 mm. This experiment shows that the haptic stimulus seems to be affected by visual stimulus when discrepancy exists between vision and haptic stimuli.

4. Conclusion

In this paper, we introduced a system that can present haptic/visual sensory fusion using mixed reality. We investigated whether visual cues affect haptic cues. Preliminary results of subjective evaluations show that users perceive an edge to be duller than a real one when presented with an overlapped CG edge with a duller curvature.

Figure 3: Mean grit sizes selected as matches for haptic, visual, and haptic/visual standards

References


