Pseudo-Haptic Feedback in a Projected Virtual Hand for Tactile Perception of Textures

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Abstract— The interface that projects a virtual hand moving in conjunction with the user's hand allows users to interact with real objects that are beyond the hand's reach. This study proposes a system that allows users to perceive an object's texture using pseudo-haptic feedback based on the visual effects of the projected virtual hand when touching an object. We designed suitable visual effects for the virtual hand based on the categories of the tactile perception of textures. Experimental results indicated that users can perceive the tactile features of objects' textures when the proposed system provided appropriate visual effects.

Fig. 1.   Conceptual idea of the proposed system.

I. INTRODUCTION

User interface that utilize hand gesture recognition are vital because objects can be naturally and intuitively manipulated via in-hand manipulation. However, such manipulations were only realized within a limited space defined by the ranges within which the hands can reach an object. ExtendedHand [1] is a system that allows users to intuitively interact with distant objects. This system uses sensors to observe the motion of a user's hand; the hand motion is then reflected to the virtual hand and projected from a video projector. Users can touch distant real objects using the projected virtual hand by only moving their hands slightly. However, users may not perceive the object's texture in such cases. Tanabe *et al.* [2] proposed a system that provides the tactile feedback corresponding to the projected virtual hand; however, users need to place their hands on a tactile display, which restricts the usage environment.

This study focuses on the pseudo-haptics that uses visual stimuli and visual-haptic perception. We proposed a mixed reality system that allows users to perceive textures of different objects based on visual effects of the projected virtual hand when it touches objects. The conceptual configuration of the proposed system is shown in Fig. 1. We referred to the categories of the tactile perception of textures felt by users and designed suitable visual effects for the projected virtual hand. Experiments were conducted to verify whether pseudo-haptic feedback was received when users touched some real objects using the virtual hand. Based on the results, we extended the application feasibility of the projected virtual hand interface by realizing a system that can provide pseudo-haptic feedback to the virtual hand, thereby developing the system with texture perception that is easy to install.
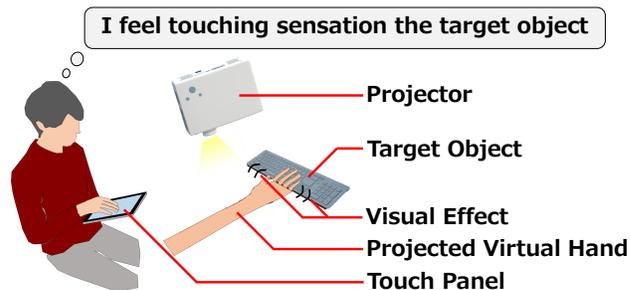
II. VISUAL EFFECTS

Humans perceive physical properties of objects by touching. Okamoto *et al.* [3] reported five components of the tactile perception of textures: fine roughness (rough / smooth), hardness (hard / soft), warmness (warm / cold), macro roughness (uneven / relief), and friction (moist / dry, sticky / slippery). We focused on five of these components such as rough, smooth, soft, warm, and cold. Fig. 2 shows the six visual effects that were studied for providing tactile perception. We designed the effects of shaking fingers and hands for perceiving roughness, those of increasing the movement speed for perceiving smoothness, those of deforming and concaving the objects for perceiving softness, and those of coloring the virtual hand red or blue for perceiving warmness or coldness.

III. EXPERIMENT

We experimentally verified whether the users perceive textures when virtual hands touch objects with proposed visual effects.

A. Procedure

Participants touched real objects with virtual hands at each visual effect (including no visual effect) and selected the visual effect that provided the best touching sensation; participants' real hands were placed on a flat surface. Experiment was performed in the following five steps. 1) Participants sat on a chair and manipulated the virtual hands projected on the table by touching the touch panel installed under the table. The touch panel senses touch points of participants' fingers, which allows the participant to control his/her virtual hand. 2) We prepared an object and let the participants touch it with their hand to perceive the texture of the object. After that, the object was placed on a table 65cm away from