# Psychophysical Influence on Tactual Impression by Mixed-Reality Visual Stimulation

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**ABSTRACT**

This paper describes the influence of visual stimulation on the tactual sense in a mixed-reality environment; i.e., how a tactual impression of a real object is affected by seeing a superimposed image of a different type of material.

If the behavior and the extent of such an influence, a sort of illusion, are investigated in detail, the objects composed of a limited variety of materials can be perceived differently. This would be useful in the field of digital engineering. Therefore, we performed various experiments systematically.

**CR Categories and Subject Descriptors:** H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—

**Additional Keywords:** mixed reality, tactual impression, texture perception, digital manufacturing, influence of visual stimulation

## 1 INTRODUCTION

Mixed reality (MR) technology, which merges real and virtual worlds, has thus far been investigated and implemented mainly in the visual sense. A user wearing a see-through head-mounted display (HMD) can see a composite image, made of a computer-generated image (CGI) mixed with a real scene, in front of him/her in real time. MR is a powerful extension of conventional virtual reality (VR) technology that can handle only a computer-generated electronic environment. MR is superior to VR in that not everything in the environment the user experiences needs to be electronically modeled. That is, only necessary items are electronically modeled, and they are merged with objects existing in the real world. Thus, MR opens up a new frontier of practical applications.

## 2 MOTIVATION

Versatile and general purpose visual or auditory displays already exist, e.g., TV monitors and audio speakers. However there are no such tactile or haptic displays and only displays with limited representative functions have been developed. In this regard, there is a room for utilizing visual MR. One possible use is superimposing electronic data onto an object while a user perceives the presence of a real object by grasping or pressing it. In fact, such a usage has been already implemented. One study [1] applied it to the practical design of automobile interiors.

The functions of this system are summarized in **Fig. 1**. This system enables a visual simulation of interior design, where a user touches real objects on which images are superimposed. Various combinations of colors and shapes can be tried out, and also materials different from what he/she actually touches.

This raises a question—how do people perceive the object if its visual and tactile information is different? He/she might feel discomfort, but the tactile sense can in fact be affected by the visual sense. If it is veridical, it can be a kind of illusion. Therefore, it is extremely interesting from a scientific viewpoint to investigate in what situation the influence (illusion) occurs, and how it affects a person. Investigating the extent of such an influence would be useful in industry, because only a limited number of objects would need to be prepared to allow the user to perceive a variety of materials.

Thus, we decided to study the influence of visual stimulation on the tactile sense in an MR environment. For the first stage, we focused on surface roughness, and performed various experiments to investigate any change in perception. These experiments provided interesting and promising results.

## 3 RELATED WORK

As mentioned above, this study is inspired by the industrial application of MR technology in [1]. Biocca *et al.* indicate that users could feel physical resistance (e.g., gravity and inertia) while moving virtual objects with their first two fingers in a VR environment without haptic devices [2]. Similar to our study, the influence in an MR environment is investigated by Nakahara *et al.* [3], who showed the influence of visual information on the tactile sense.

## 4 EXPERIMENTS

### 4.1 MR System and Preparation

The experimental overview of this study is shown in **Table 1**. In the experiments, we adopted an MR system with a video see-through mechanism that visually merges the real and virtual worlds. Wearing an HMD, the user can see a CGI texture-mapped onto a CG model with high geometric precision.

**Table 2** describes the specifications of the HMD. For use as

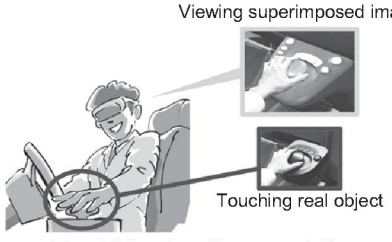


**Fig. 1** Mixed reality presentation

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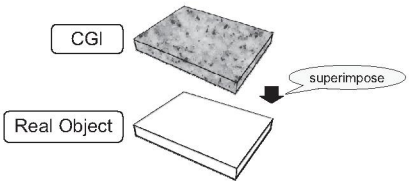
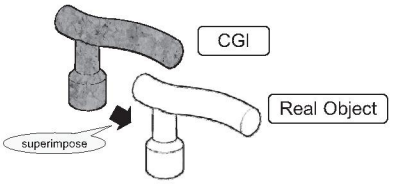
**Table 1** Experimental overview

| | Ex. 1.1 | Ex. 1.2 | Ex. 2.1 | Ex. 2.2 | Ex. 2.3 |
|---|---|---|---|---|---|
| Real Object | plastic | cloth/leather | plastic | | |
| CGI | plastic | cloth/leather | various textures | | |
| Surface Shape | flat surface | | | curved surface *without *a prior* knowledge | curved surface *with *a prior* knowledge |
| Image |  | | |  | |





texture images, we prepared several materials, as shown in **Fig. 2**. Thirteen subjects participated in each experiment.

### 4.2 Preliminary Experiments

We prepared four plates with different roughnesses, made by rapid prototyping (RP), which is a process of creating a physical 3D-object from a geometrical data with high accuracy and convenience (**Fig. 3**). Pairs of these plates with the same roughness were placed in front of the subject, and texture images of plates with different roughness were superimposed onto each of them. The subject touched them and identified which he/she felt rougher under the pair comparison method.

It can be said that the subjects felt a difference between the objects, even though they touched the objects with same roughness. This made it clear that the tactile sense is affected by visual information.

### 4.3 Main and Extended Experiments: Texture Representation by MR Visual Stimulation

We mapped a variety of texture images onto a plate that appeared to have similar roughness compared to the plates in the images. We then extended the experiments to curved objects, which have four different surface roughnesses. At this stage, the method of touching was changed from "stroking" to "stroking and grabbing," to allow the subjects to handle the objects naturally.

Using flat surfaces the experiment demonstrated that subjects perceived the feeling of the mapped material when the coarseness was visually and tactually similar. However, when the surface was curved, they felt discomfort of hardness for certain materials made of cloth and leather. This might be caused by the peculiar nature of grabbing; the subjects felt hardness more clearly than when stroking [4]. This discomfort did not decrease even though the subjects were given *a prior* knowledge that the object they would be touching was going to be hard.

## 5 Summary and Concluding Remarks

In this paper, we performed experiments to determine the effects of visual stimulation on tactile senses when a textured image was superimposed onto a real object in an MR environment. The results can be summarized as follows:

(1) Tactual impressions can be intentionally changed by providing appropriate visual stimulation.
(2) When superimposing the texture image of existing physical materials onto an artificial RP product, human subjects perceived the expected tactile illusion only when the coarseness of visual and tactile textures was almost the same.
(3) It seems unreasonable to superimpose the texture image of a soft material onto a harder material, such as a plastic.

**Table 2** Specifications of HMD

| HMD Canon VH-2002 | |
|---|---|
| Viewing Angle (V/H) | 37/51 deg |
| Weight | 327 g |
| Resolution | VGA (640 × 480 pixels) |
| Video I/O | NTSC |

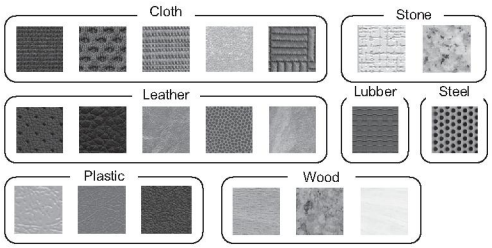



**Fig. 2** Various texture images to be superimposed

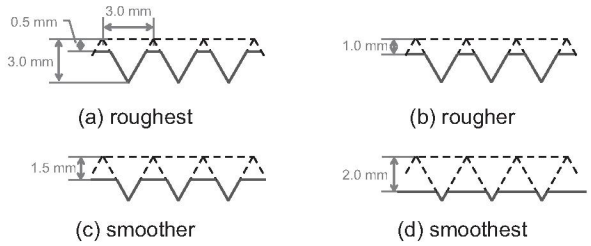



**Fig. 3** Four different roughnesses of RP objects (Solid lines correspond the surface line)

This study produced very interesting and promising results. It can be said that we can create a tactile illusion for RP objects only if an appropriate texture image of a solid material is selected carefully (e.g., wood or stone, and not leather).

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