Distinguishable virtual haptic textures to understand multisensory sensation*

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Abstract. The perception of natural surfaces involves several senses including vision and touch. Several studies have shown cross-modal interactions between the two modalities. However, the integrative mechanisms underlying this process remain unclear. Therefore, we aim to explore the mechanisms involved in the visuo-tactile perception of textures, namely how tactile and visual information are integrated and merged to generate the subjective perception of textures. But one of the difficulties encountered in haptic studies of real textures is to generate tactile feedback that faithfully reproduces the natural surfaces. To overcome this problem, we selected several texture whose vibrotactile signature were recorded. From these signature, we created a database that will be used in the coming electrophysiological and psychophysical studies. First, we performed a preliminary psychophysical task in which the participants were asked to distinguish pairs of textures based on haptic feedback only. The results showed a success rate of 0.82 ± 0.04 and thus demonstrated that discrimination of the rendered textures is possible without being trivial. The next step would be to perform a study about how people perceive visuo-tactile textures with co-localised visual and tactile dimensions.

Keywords: Haptic textures · Psychophysics · Multisensory Interaction.

1 Introduction

When we explore an object or touch a natural surface, both vision and touch provide information about the properties of the object or the surface. The information gathered by each individual sense have been widely investigated [1, 3]. In the past, the visual sense was considered dominant over touch. But later studies have shown that visuo-haptic integration can be achieved in a statistically optimal way [2]. However, it remains unclear how the information gathered by the two modalities are fused together to enable the perception of textures. To fill this gap, we propose an original approach that aims to create a new dataset of visuo-haptic textures recorded with the bare finger, which will be used to perform psychophysical experiments and electrophysiological recordings.

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2 Methods

2.1 Texture recording

We recorded tactile interaction with everyday fabrics to use these recordings in psychophysical tasks. We used five common surfaces: black corduroy, regular denim, stretch denim, black flag banner and a transparent plastic with 3mm-embossed dots. The selected textures were chosen to provide rather similar haptic and visual feedback. Each sample is a 3x9.5cm rectangle glued to a piece of wood of the same dimension. During the recordings, each surface was placed on a top of a force sensor (Nano 17 Titanium, ATI Inc.). A lightweight accelerometer (PCB 352A21) was strapped around the right index fingertip of the experimenter to measure the vibrations that were generated during the texture exploration. The normal and tangential forces applied on the finger and the acceleration were measured simultaneously during the exploration of the different surfaces with a sampling rate of 10kHz. We displayed a slider on a Touchscreen (DFRobot LCD screen, 183x100mm) placed next to the recording setup, which moved at a constant speed of 4cm/s. It served as a visual guide to keep the exploration speed constant. A total of three trials were recorded for each texture.

2.2 Psychophysical task

In the second part, we used the recorded tactile signals to perform a psychophysical experiment on haptic feedback. Three subjects (3 men from 22 to 24 years old, all right-handed) were recruited to participate in this experiment. The possible combinations of textures within the previously collected set of fabrics were successively presented to the participants by the mean of an tactile actuator (MM3C, Tactile lab, 36x9.5x9.5mm) held between the thumb and the index of their dominant hand. The participants could see the experimental setup and the tactile actuator. For each trial, they were asked to compare two successive vibrations. After the trial, they answered whether the vibration were the "same" or "different". To enhance the reliability, all pairs of textures were repeated 10 times in a pseudo-random order. During the entire experiment, participants listened to white noise delivered through headphones to avoid auditory cues.

3 Results

We conducted an experiment to test whether participants could discriminate the selected textures using only tactile feedback. The results of all the participants were used to compute a confusion matrix Fig. 1. The rows of the confusion matrix represent the textures presented first to the participants and the columns represent the one presented second. The average ratio of correct answers was 0.82 ± 0.04. These results show that people mostly felt the difference across the rendered textures when played by the vibrotactile actuator. The participants reported two pairs as quite similar. The texture 3 and 4 were considered different

23% and 30% of the time depending on the presentation order. When textures 2 and 4 are compared, they are only perceived in 57% and 42% of the cases as different. Interestingly, they correspond respectively to black flagbanner and stretch denim, which are rather distinct.

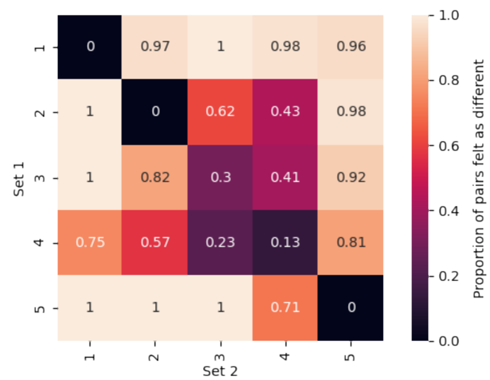

Fig. 1. Confusion matrix of the experiment's responses. The columns and rows represent the different haptic textures presented, namely: 1-plastic, 2-black flag banner, 3-regular denim, 4-stretch denim, 5-black corduroy. The matrix entries represent the frequencies for which the two vibrations were considered different.

4 Discussion

In this study, we attempted to select and record in active touch conditions a dataset of textures on which tactile confusion could occur despite rather clear overall dissimilarity. To test the success of the attempt, we conducted an experiment on the perception of these recorded textures. This experiment showed promising results since some level of confusion occurred. The next step is to update this dataset and explore how humans perceive visuo-tactile surfaces when the visual and tactile dimensions are collocated. We aim to investigate which parameter alters multimodal perception the most and if a subtle change in the tactile or visual dimension is noticed by humans.

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