Rendering Method of 2-Dimensional Vibration Presentation for Improving Fidelity of Haptic Texture

Junya Kurogi[1], Satoshi Saga[1]

[1]Kumamoto University, JAPAN

Contact email: {kurogi,saga}@saga-lab.org

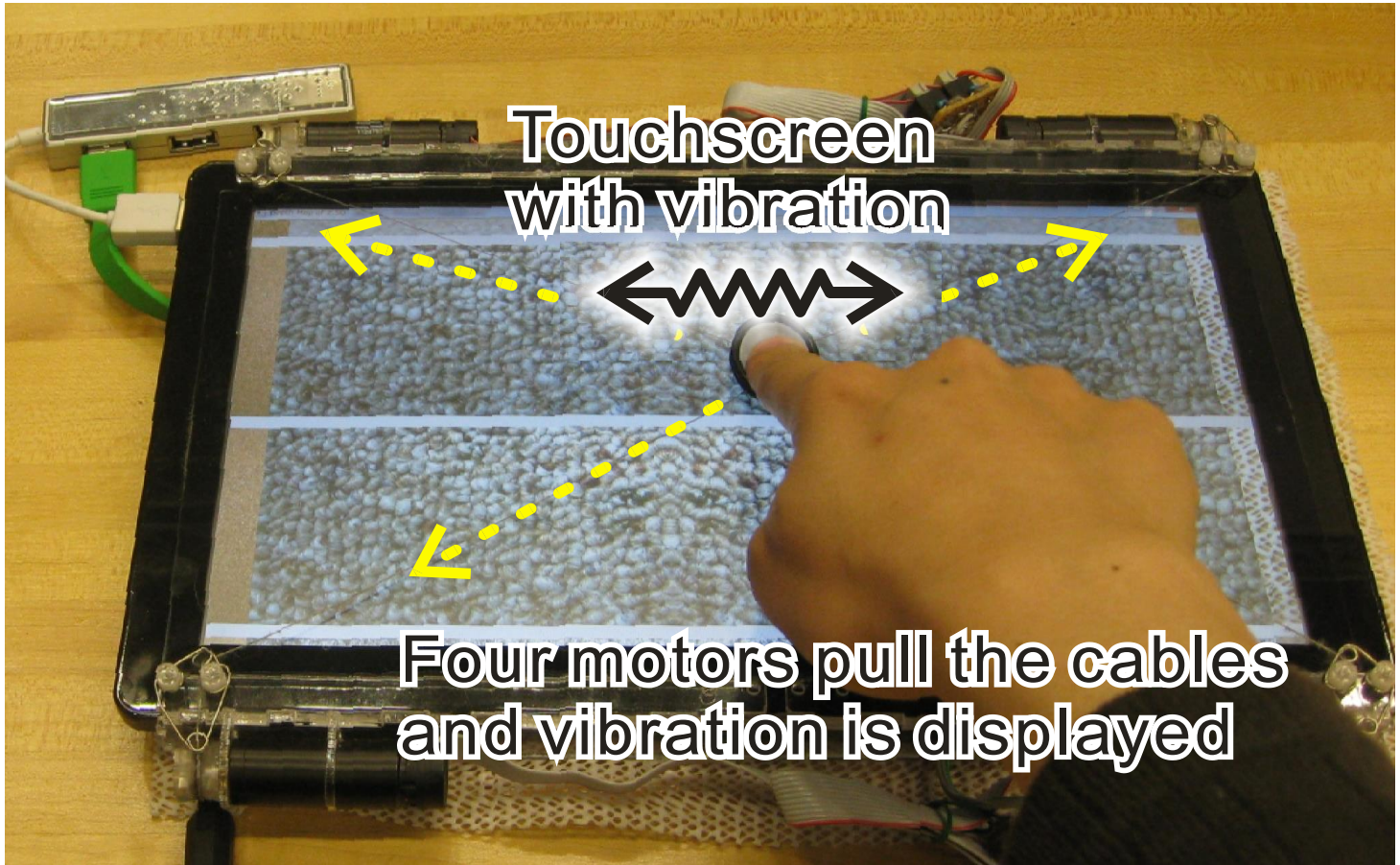
Kumamoto University

Junya Kurogi

- Junya Kurogi received the BS and MS degrees in engineering from Kumamoto University in 2017 and 2019, respectively. He had been engaged in research on a tactile display employing virtual reality. Since 2020, he has been an engineer at Nishi-Nippon Railroad Co., Ltd.

Our goal

- Developing a **rendering method** for texture display
  - Based on two dimensional vibration hardware
  - From the recorded vibration, we reproduce the fidelity of the texture

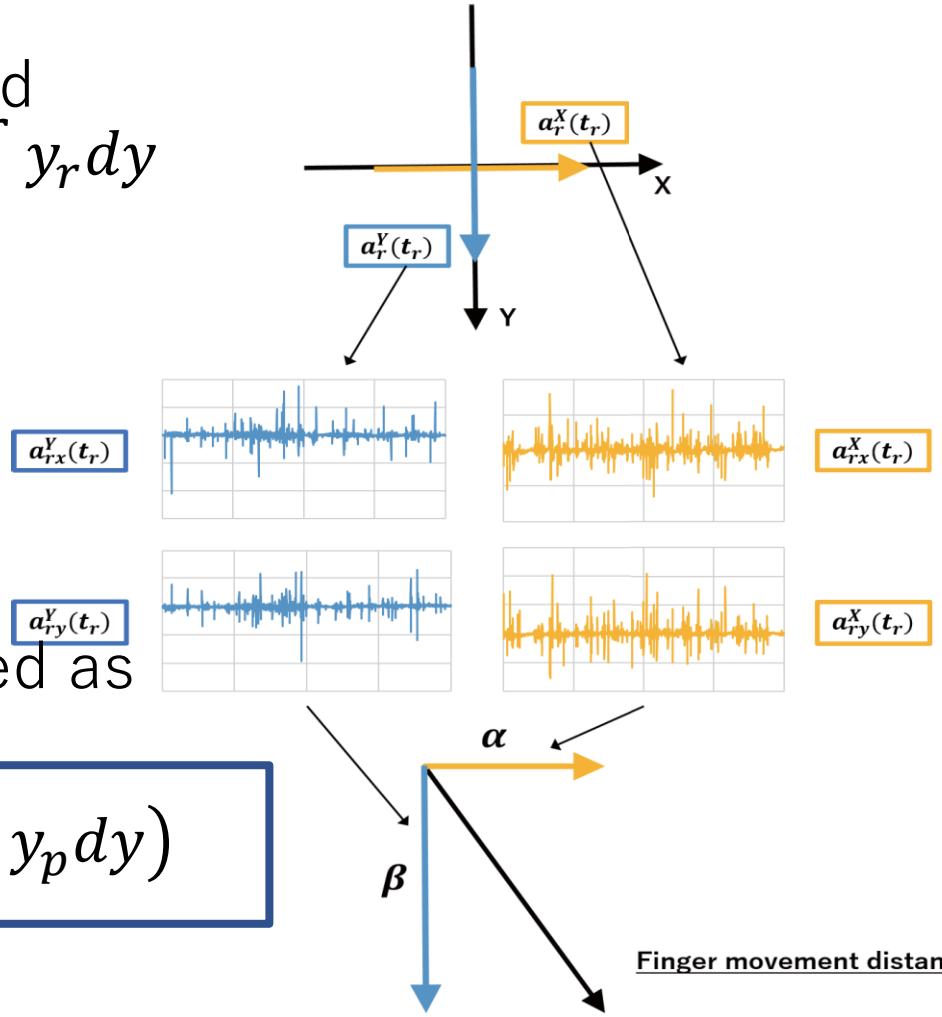


Displaying method of recorded acceleration

The recorded acceleration $\boldsymbol{a}_{r_d}^{\mathcal{D}}$ is described by the movement length of the finger $\int x_r dx, \int y_r dy$

$$\boldsymbol{a}_r^{\mathcal{D}} = \boldsymbol{a}_{r_x}^{\mathcal{D}} + \boldsymbol{a}_{r_y}^{\mathcal{D}} = \boldsymbol{a}_r^{\mathcal{D}} \left(\int |x_r| dx \, , \int |y_r| dy \right)$$

$\mathcal{D} \in x, y$ $(direction\ of\ vibration)$,
$d \in x, y$ $(direction\ of\ movement)$



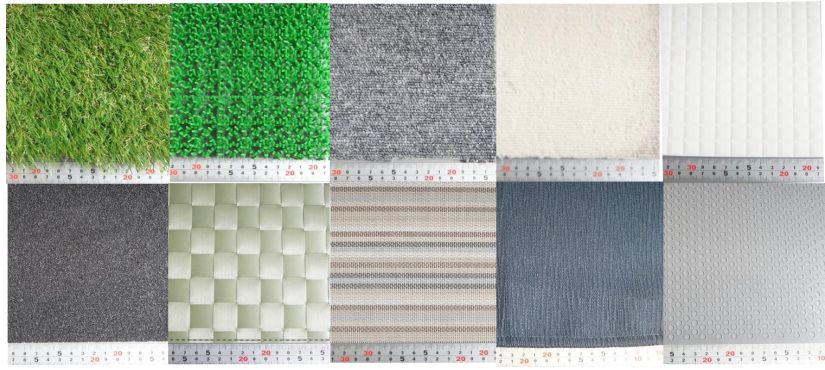
Thus , the replaying acceleration $\boldsymbol{a}_p$ is described as

$$\boldsymbol{a}_p\left(\int x_p dx, \int y_p dy\right) = \alpha \cdot \boldsymbol{a}_{r_x}^{\mathcal{D}}\left(\int x_p dx\right) + \beta \cdot \boldsymbol{a}_{r_y}^{\mathcal{D}}\left(\int y_p dy\right)$$

Where, $\Delta \boldsymbol{x}_p = (\alpha, \beta)$, $\left|\Delta \boldsymbol{x}_p\right| = 1$

Problem of the displaying method

- Many random textures can be reproduced by the method

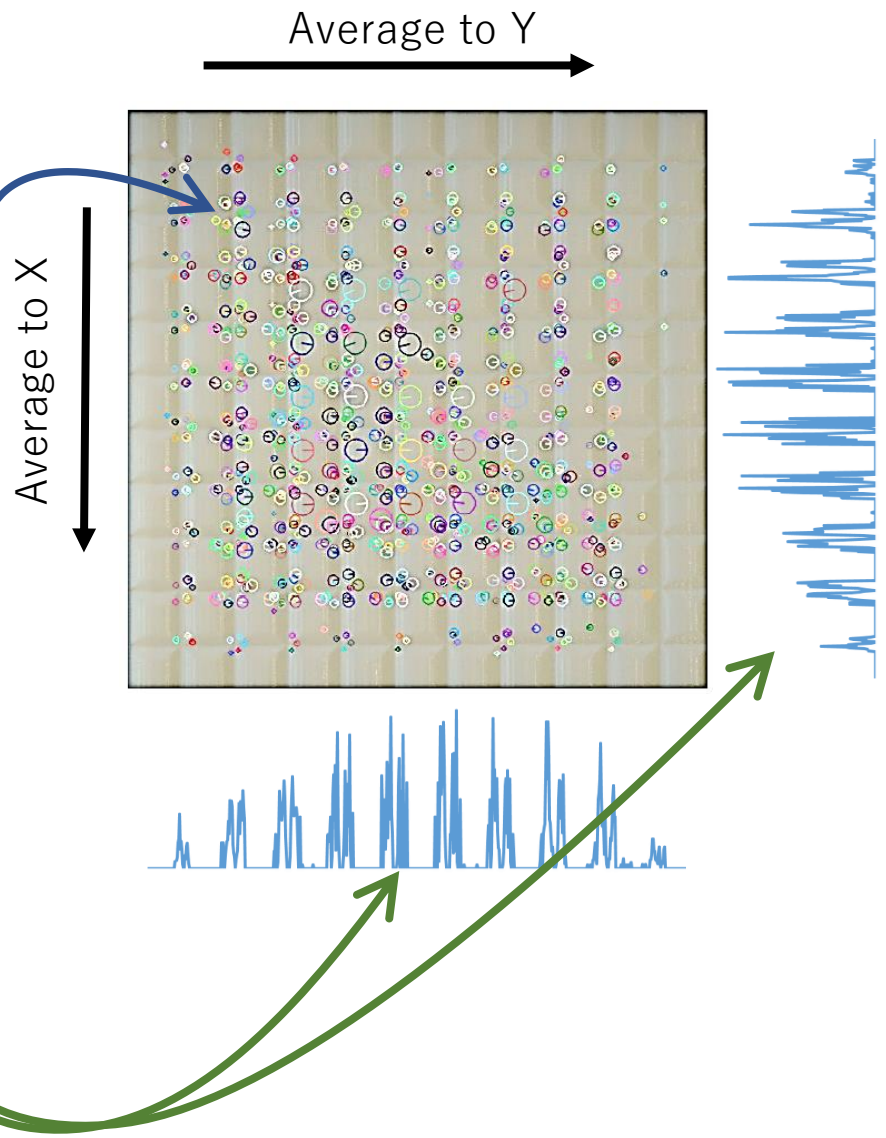


- In some textures, the method cannot reproduce the fidelity
  - **Certain spatial frequency textures**, such as tiled-floor

- We employ **image features**

Use of image features

1. Acquire features using **AKAZE**
2. Extract the **size information**
3. Obtain averaged **one-dimensional** information
4. **Augment the size information**

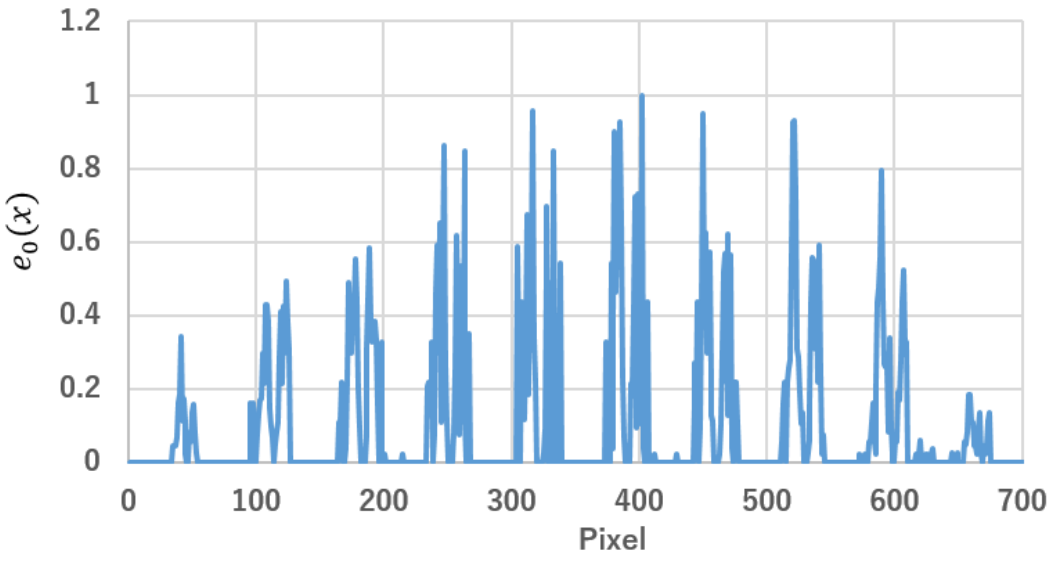


Further processing

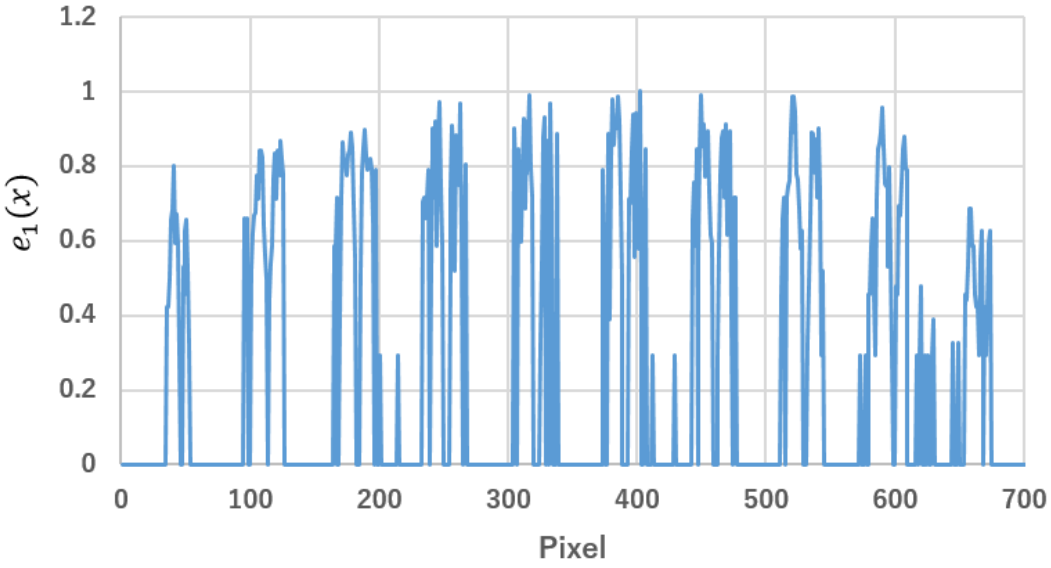
- The vibration of no feature area is diminished by the augmentation

- To avoid this diminishing, we apply the logs

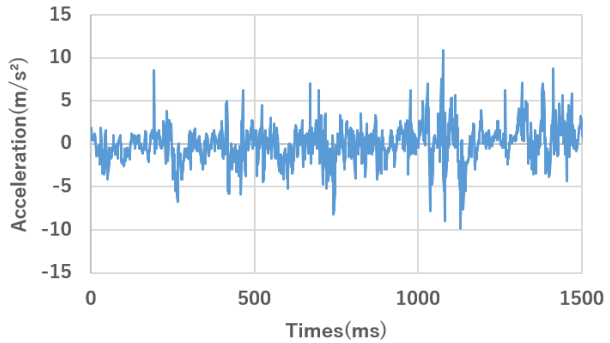
e_0: before applying logs



e_1: after applying logs



Augmented vibration applying image features



Acceleration of tile

×

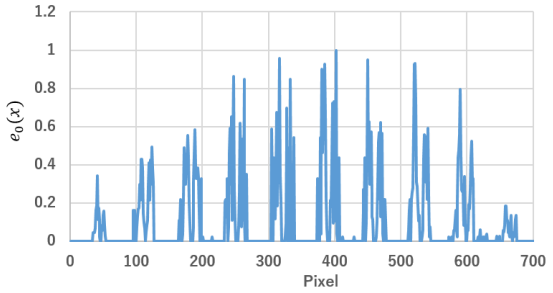
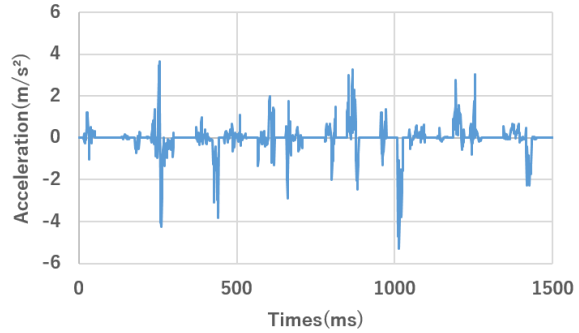
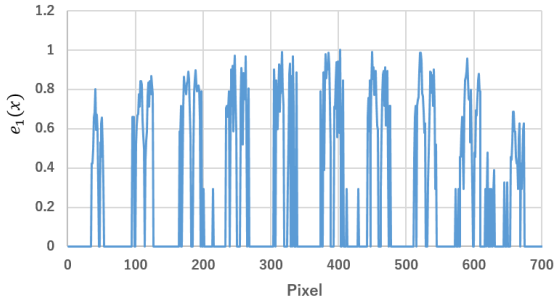


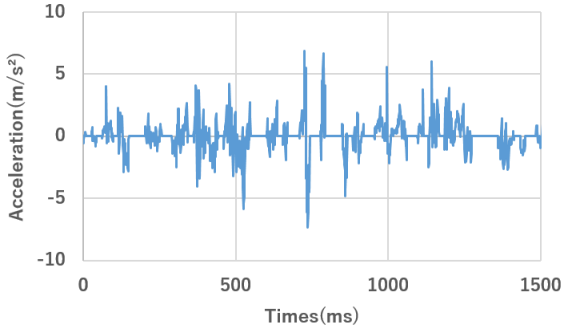
Image feature(e_0)



×



Log scaled image feature (e_1)

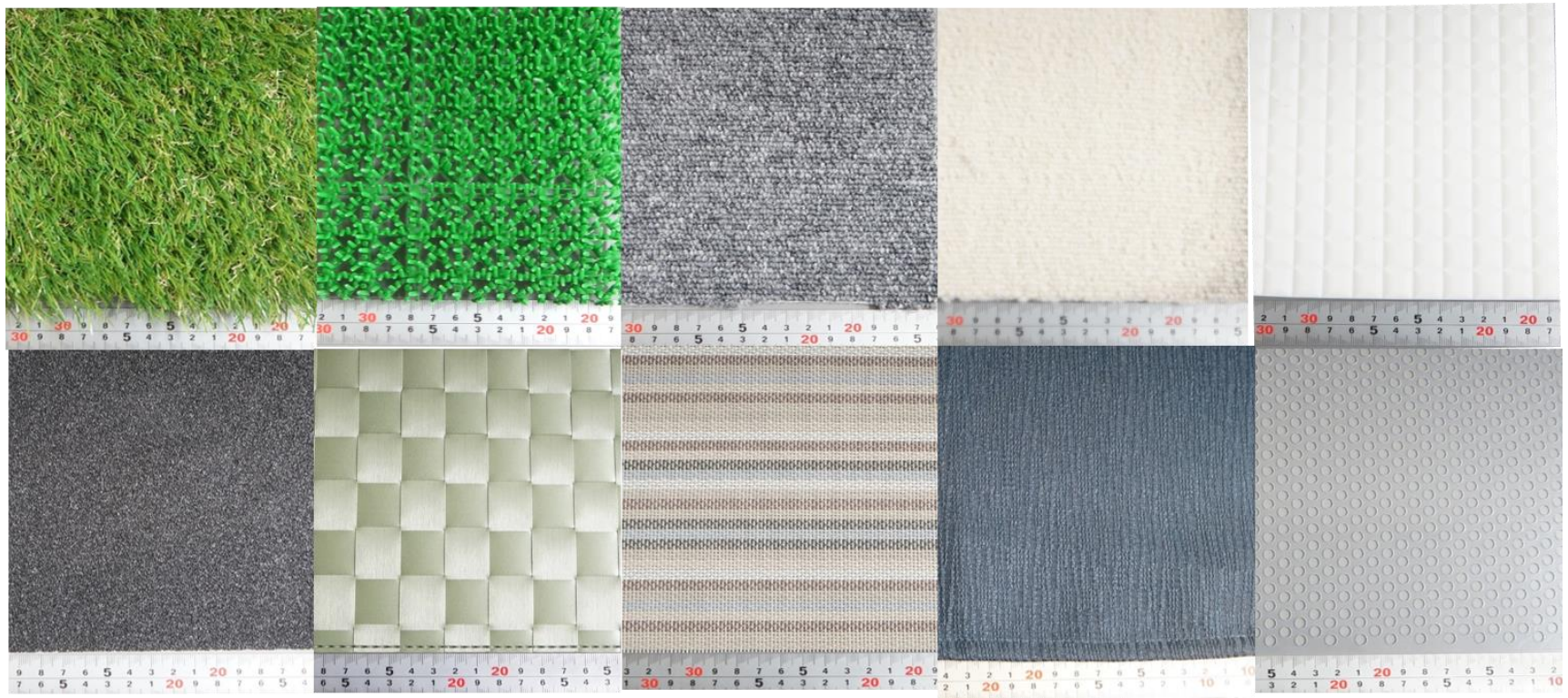


$$\boldsymbol{a}(t) = \begin{cases} a_p^X(t) & \text{(one dimension)} \\ \boldsymbol{a}_p(t) & \text{(two dimension)} \\ a_p^X(t) \cdot e_{x0}(x,y) + a_p^Y(t) \cdot e_{y0}(x,y) & \text{(image feature)} \\ a_p^X(t) \cdot e_{x1}(x,y) + a_p^Y(t) \cdot e_{y1}(x,y) & \text{(log scaled image feature)} \end{cases}$$

Textures for experiment

- We prepared 10 types of textures and collect the acceleration information

✓ Artificial Grass1 ✓ Artificial Grass2 ✓ Carpet1 ✓ Carpet2 ✓ Tile



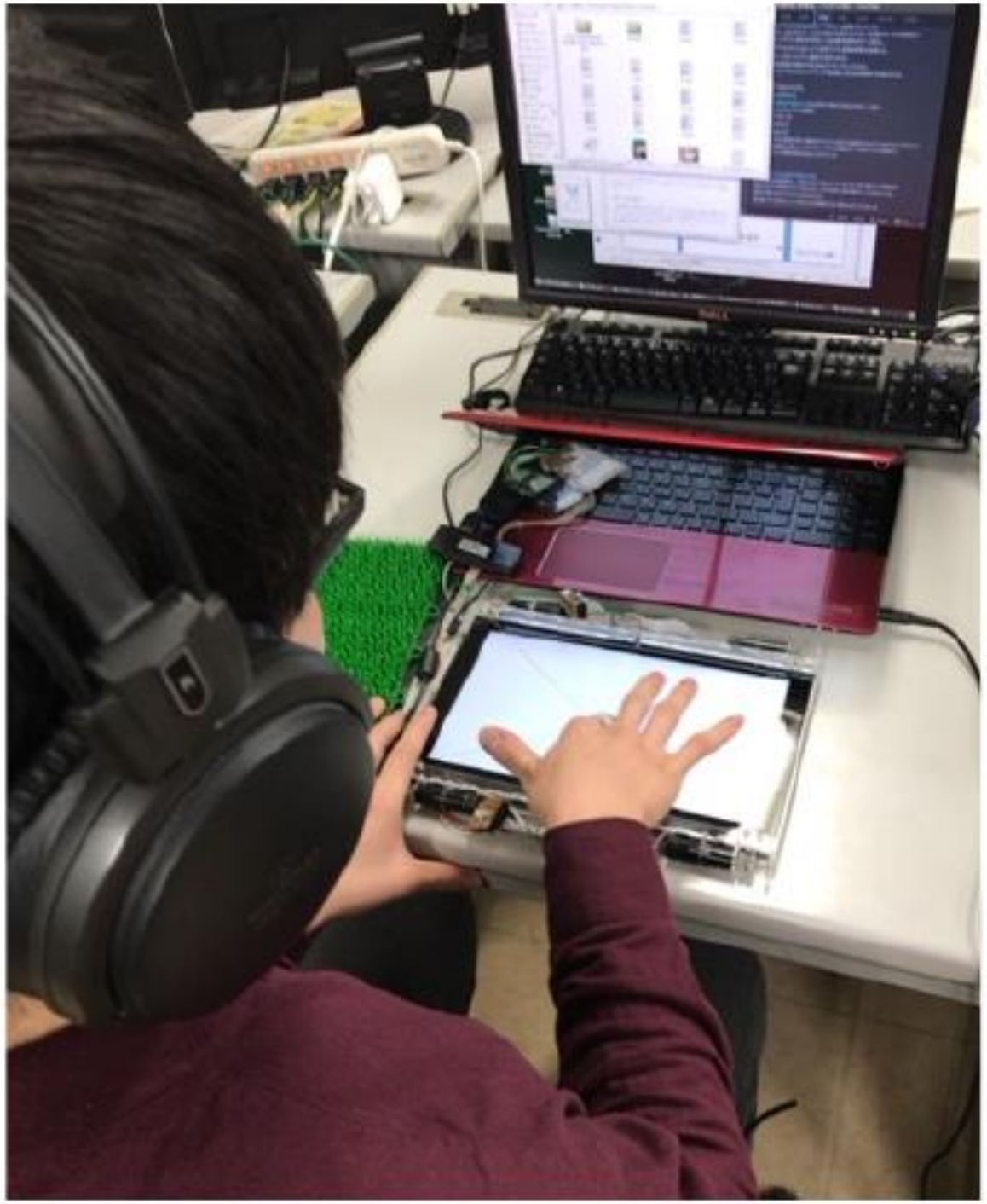
✓ Sand Paper ✓ Place Mat1 ✓ Place Mat2 ✓ Place Mat3 ✓ Punched Plastic Sheet

Experiment procedure

- Rendering method for comparison
  1. One dimensional vibration
  2. Two dimensional vibration
  3. Feature augmentation e_0(without log)
  4. Feature augmentation e_1(with log)

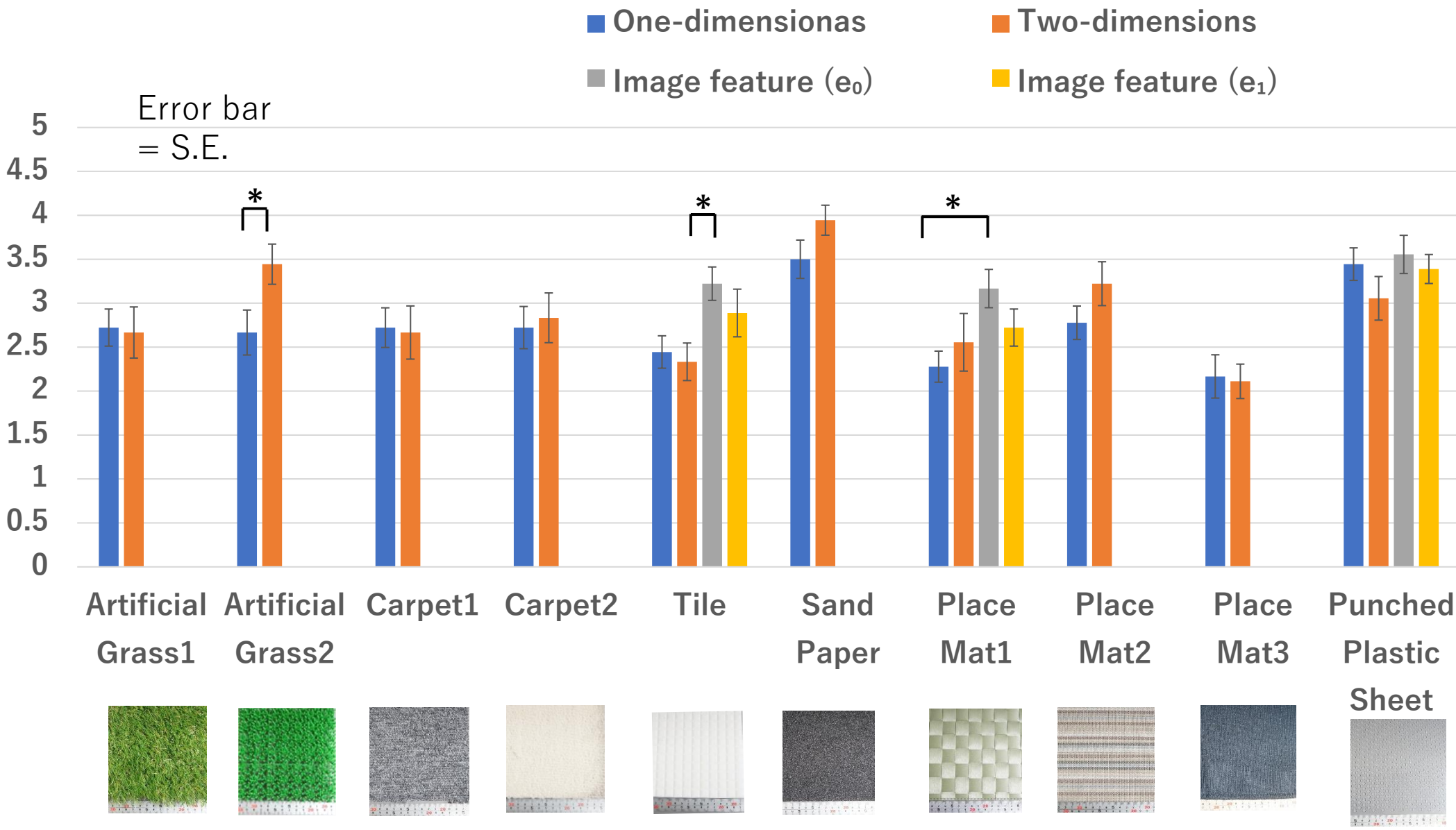
※For the textures other than Tile, Place Mat1 and Punched Plastic Sheet, we applied the method of 1, 2 only

- Evaluation method
  - ✓ 5 stages Likert scale
- Participants
  - ✓7 healthy men aged 22 to 24.
  - ✓They wore headphones and eye mask to remove the visual/auditory effect

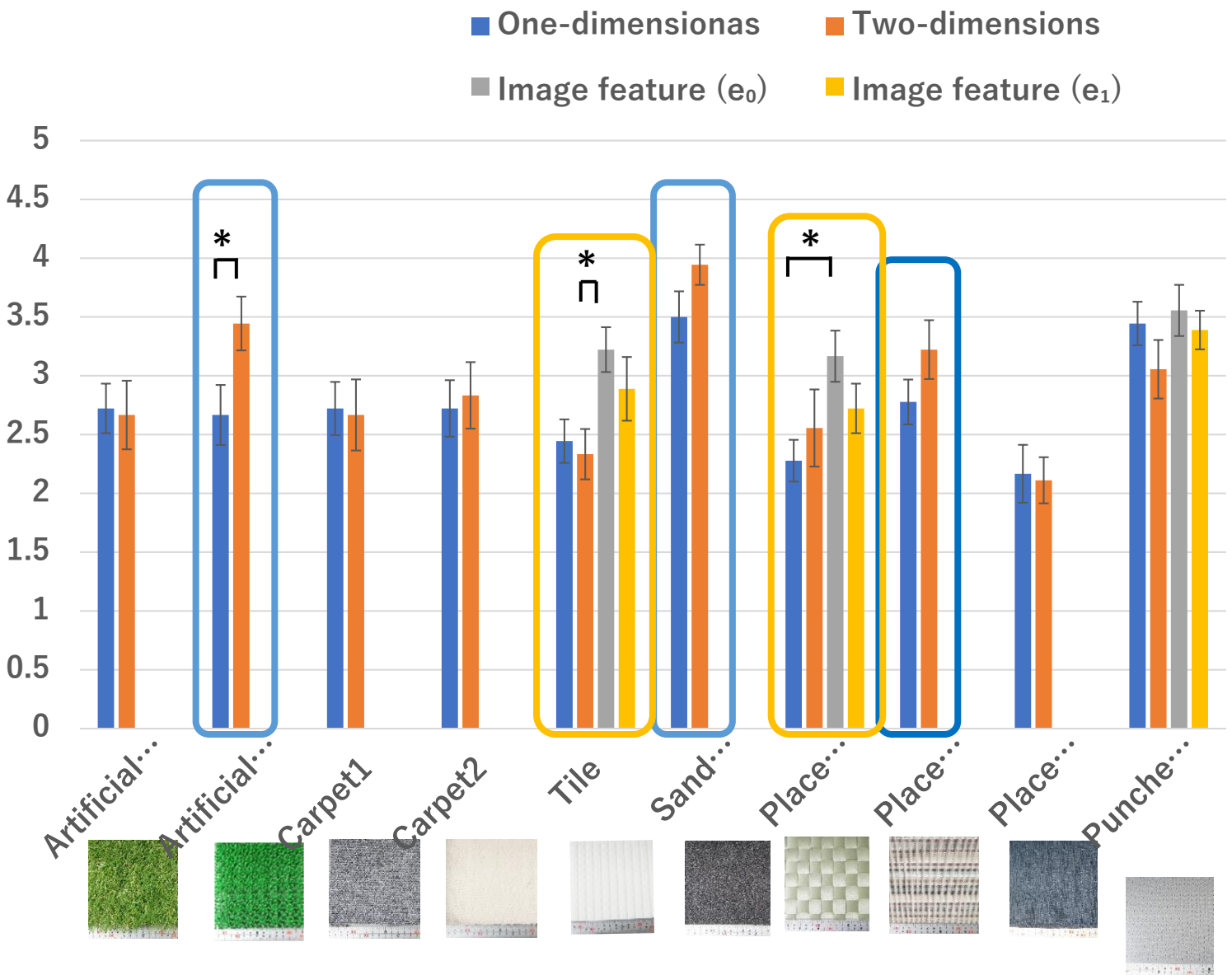


Result

* shows $p < 0.05$ under t-test or $\alpha < 0.05$ under Tukey's test

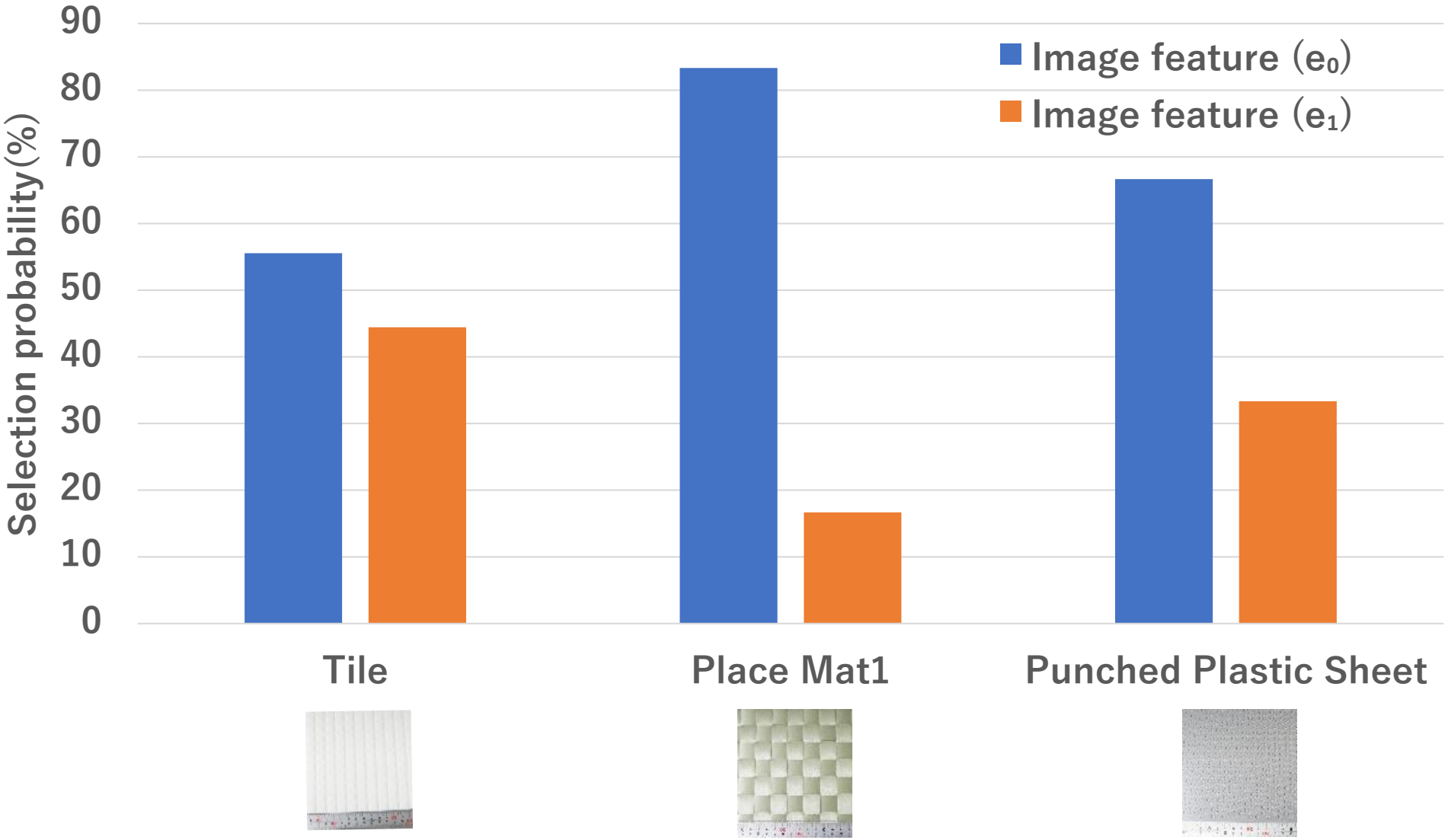


Discussion



- The proposed method is suitable for presenting textures with **random spatial frequencies** and a relatively **hard tactile sensation**
  - ✓Artificial Grass2, Sand Paper, Place Mat2
- The method is suitable for some texture with a constant spatial frequency
  - ✓Tile, Place Mat1
  - ✓Especially, the image feature e_0 shows significant difference

Comparison between image feature augmentation methods



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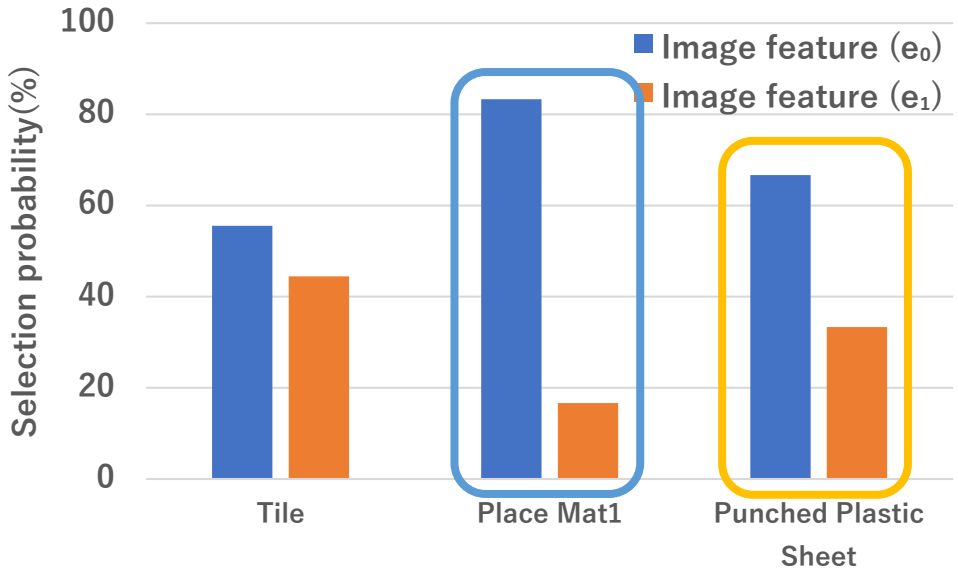
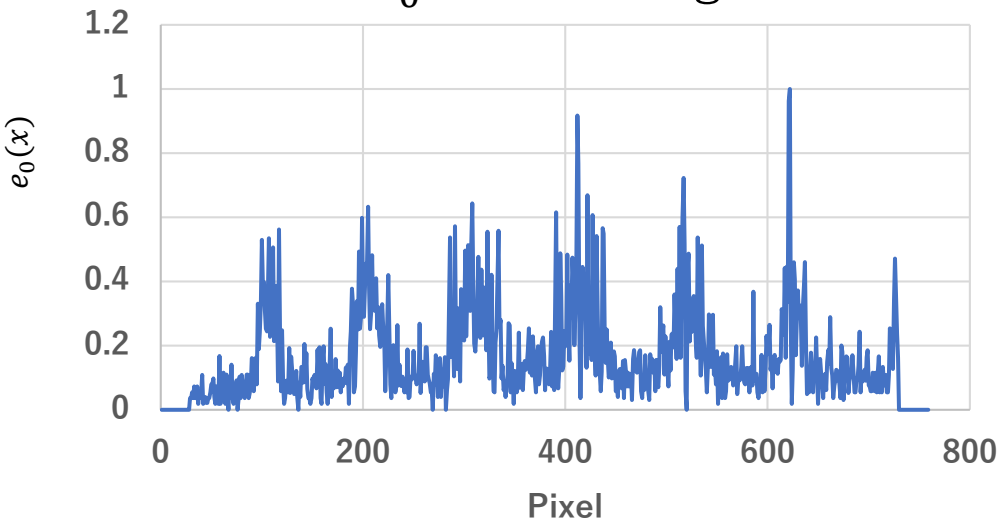
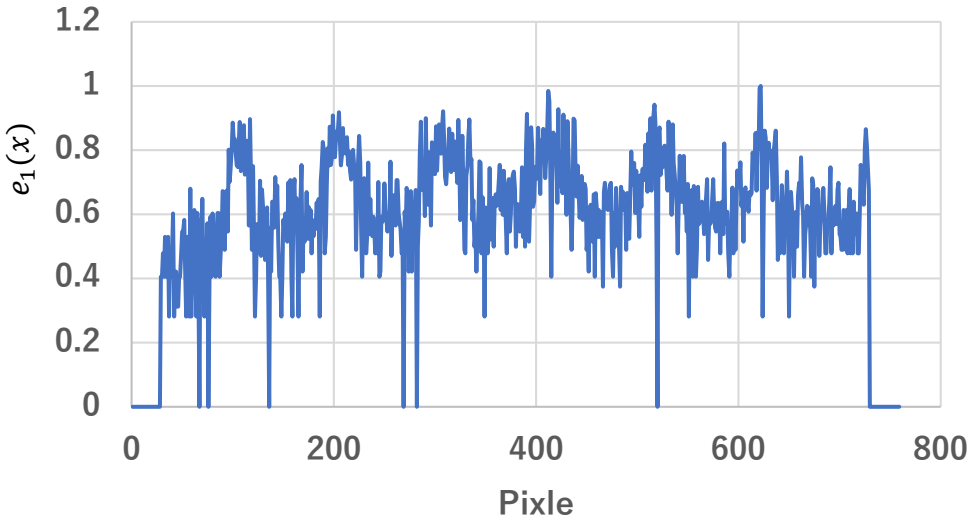


- e_0 has high fidelity on Place Mat1
  - e_0 : Enhancement of feature points
  - e_1 : Reducing the diminishing of vibration
  - ➢ Longest spatial period induces the enhancement of feature point than vibration intensity
- For short spatial period, the augmentation is not effective in Punched Plastic Sheet

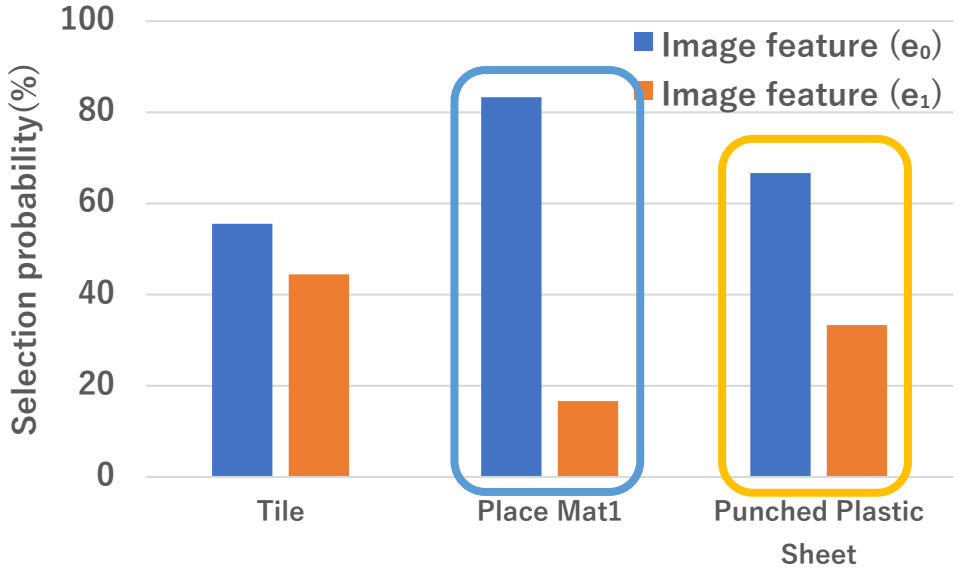
e_0: without log



e_1: with log



Discussion



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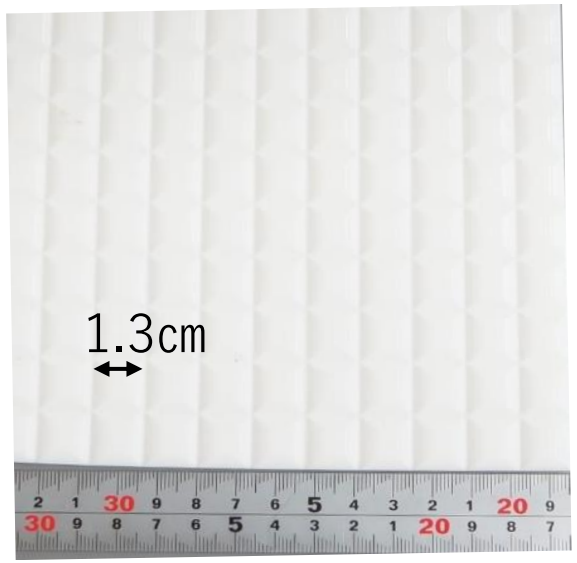
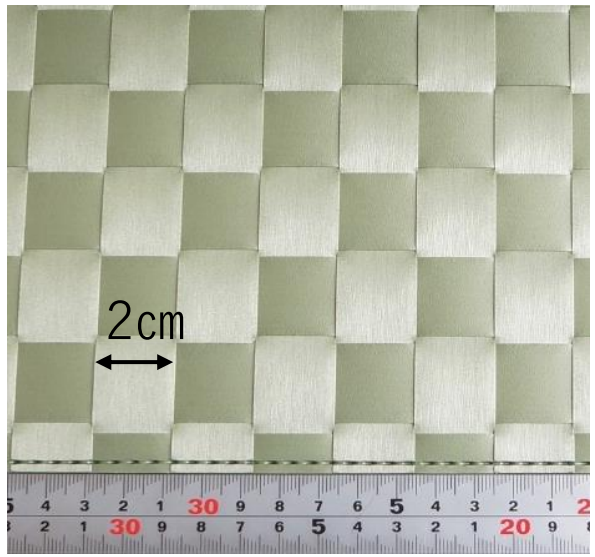
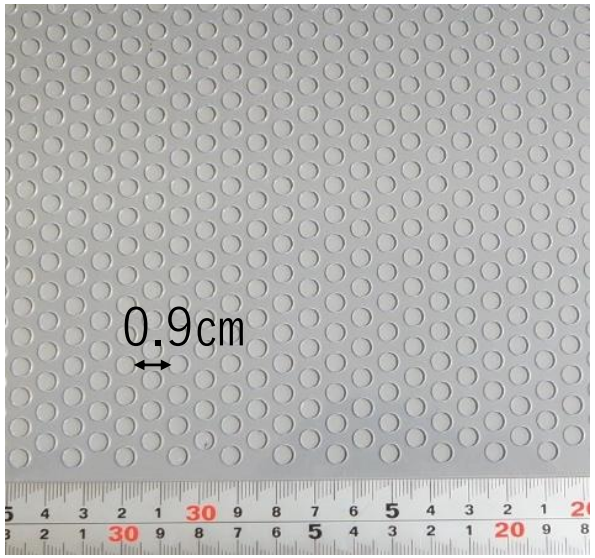
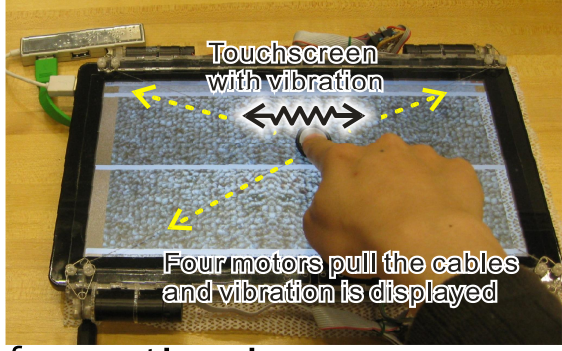






Conclusions



- Purpose
  - Proposal of a presentation method that accurately presents vibration information in the two-dimensional direction
  - Proposal of vibration presentation method using superimposition of image features
  - Verify the tactile reproducibility of each method
- Result
  - Two-dimensional vibration presentation is suitable for hard, random textures with spatial frequencies
  - An image feature augmentation method is useful for textures with a constant spatial frequency
- Future work
  - Presentation of softness by dynamic vibration control
  - Establishment of a texture selection method suitable for using the image feature superimposition method