

# Development and evaluation of a handheld type 6 DoF midair haptic device using asymmetric vibration and a presentation force vectoring mechanism

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## Research Article

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# Abstract

This paper describes a handheld type aerial haptic device with 6 DoF (degree of freedom) using pseudo-haptics by asymmetric vibration. By introducing a original presentation force vectoring mechanism, 6 DoF force sense presentation and compactness suitable for handheld use with a small number of vibrators are realized together. In addition, a relationship between the drive input and output (presentation force sense) of the developed device is formulated, and its inverse problem solving method for obtaining the drive input that realizes a desired presentation force sense is derived. Furthermore, a user test clarified the direction in which this device can / cannot effectively exert force.

# Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

# Figures

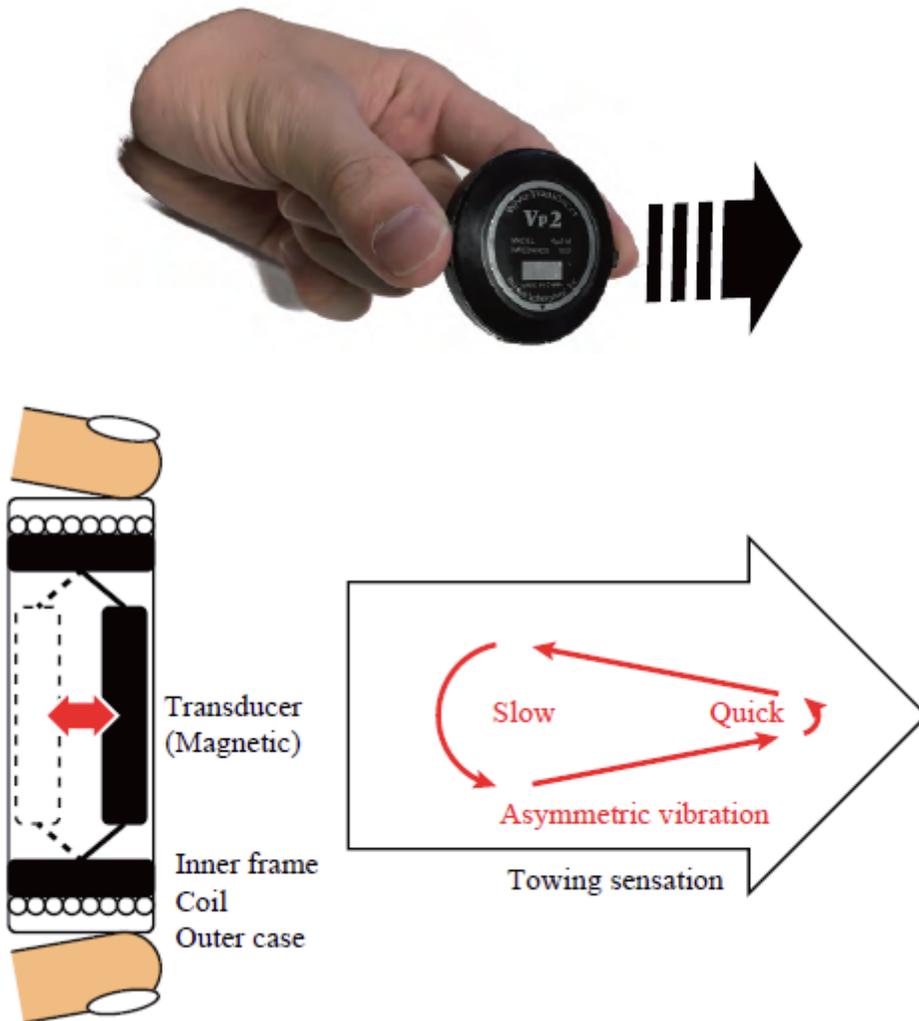


Figure 1

Generating traction sensation by asymmetric vibration

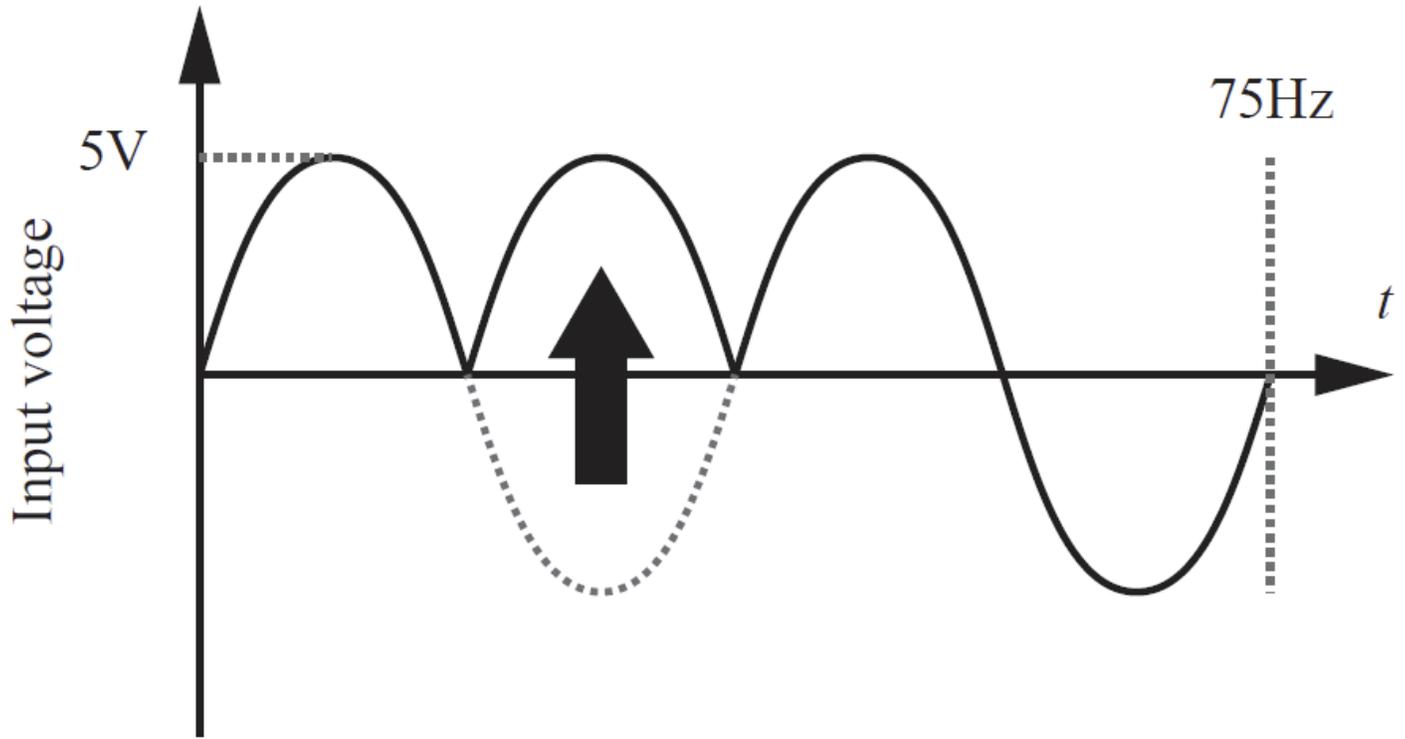
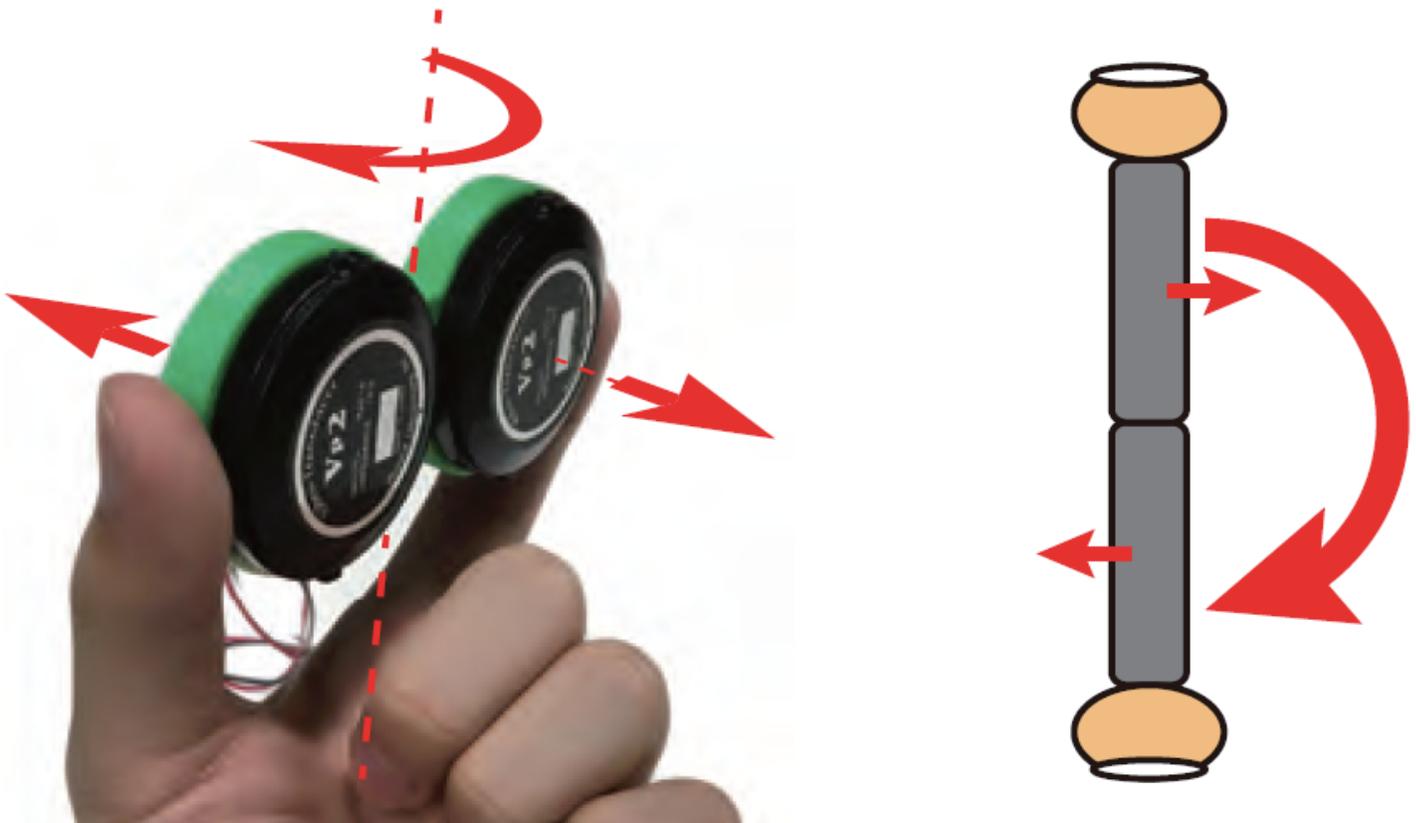


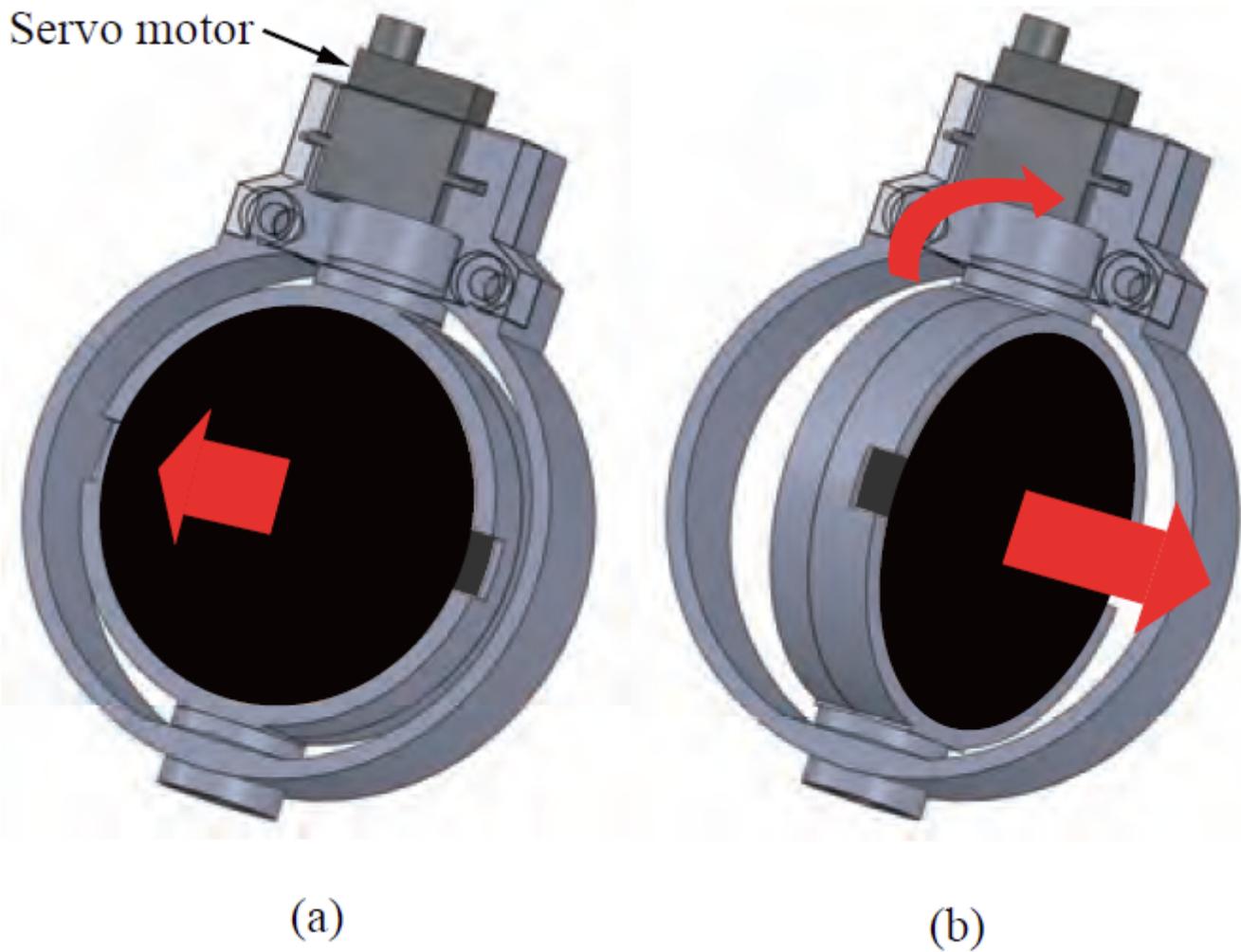
Figure 2

An approximate input voltage waveform for asymmetric vibration



**Figure 3**

Synthesis of rotational sensation by combining two vibrators (translational traction sensation)



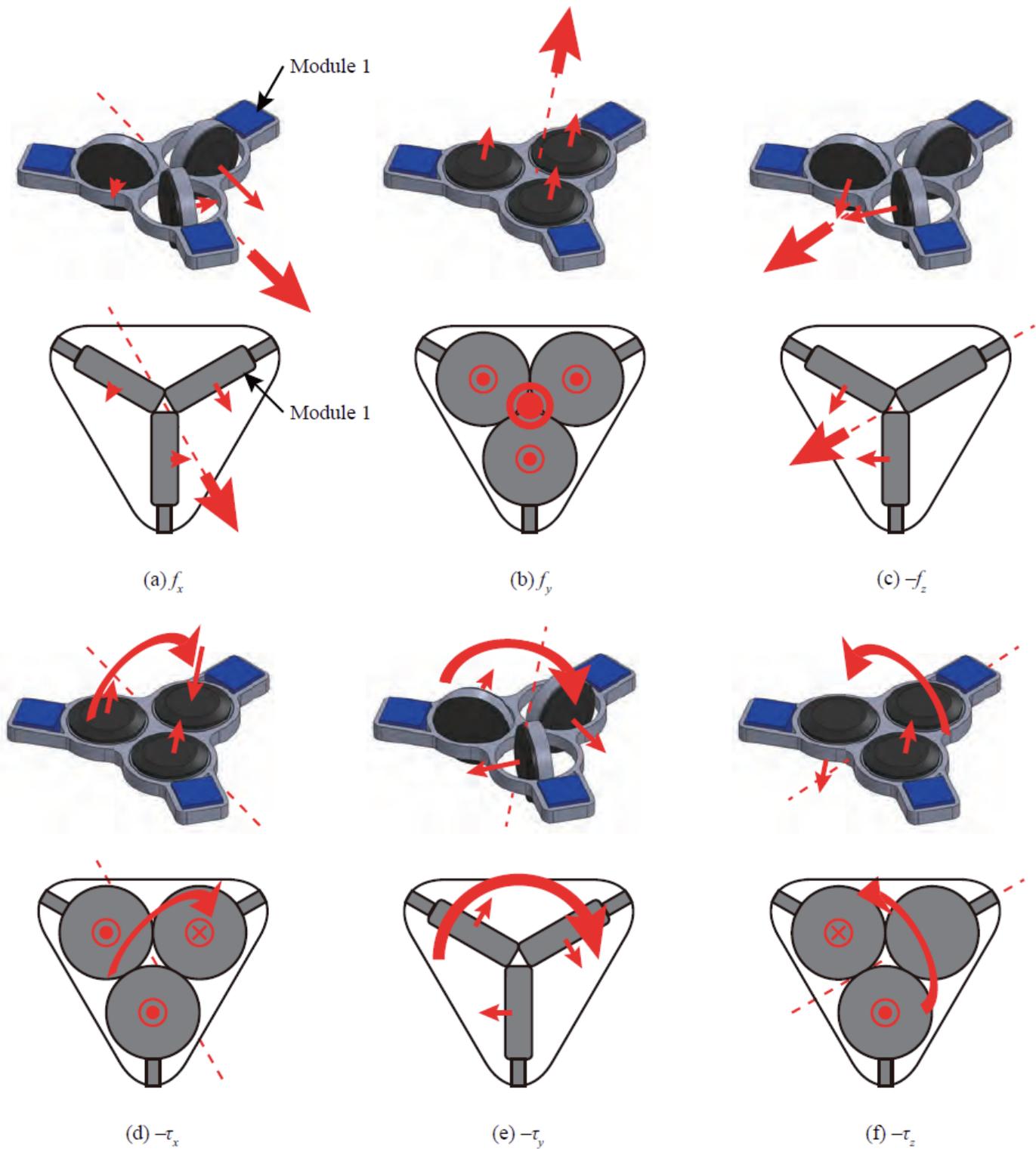
**Figure 4**

A mechanism for vectoring the presented force (traction sensation). (a) shows a standard state, (b) shows a maximum vectoring state



**Figure 5**

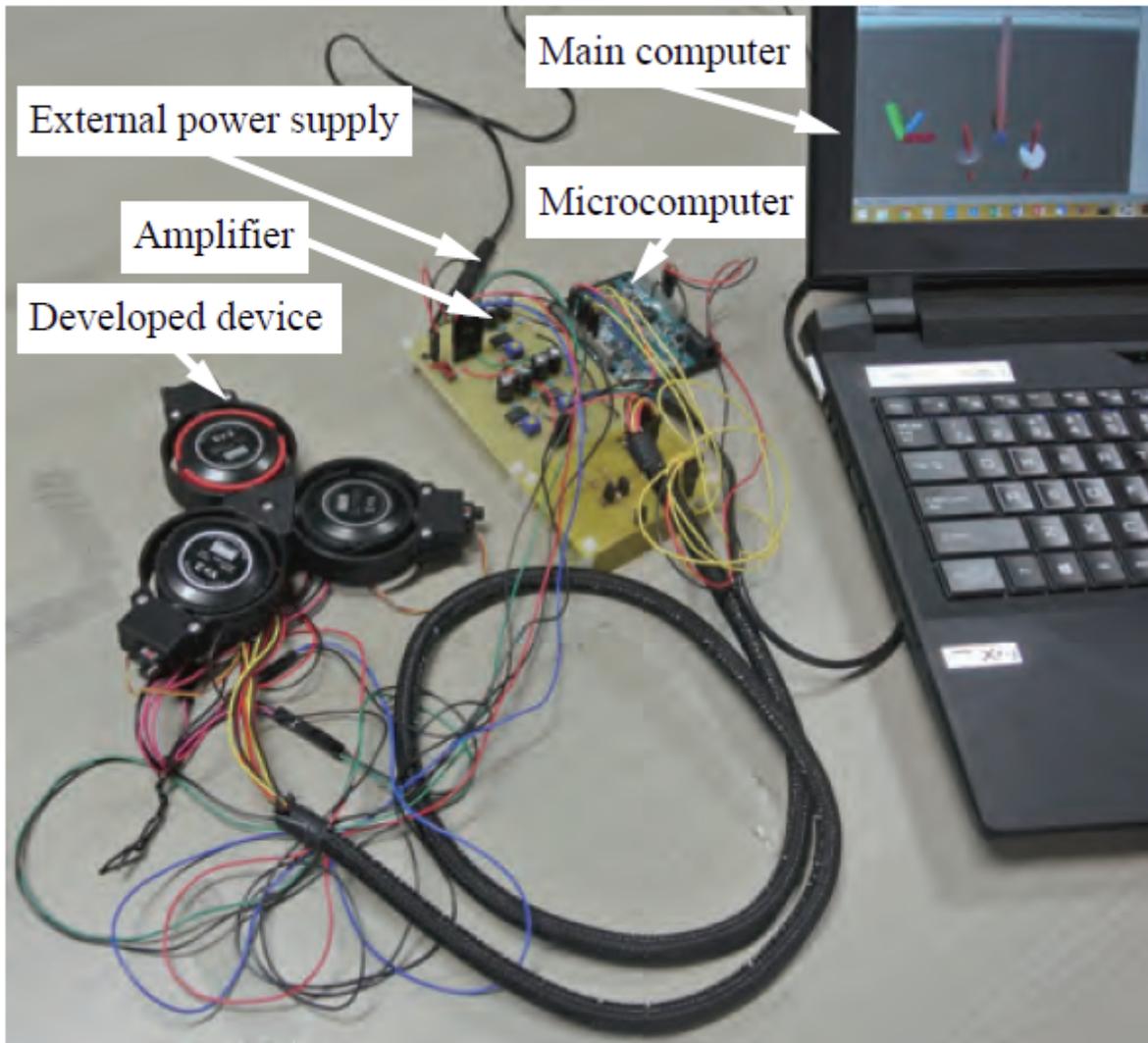
An overview and a local coordinate system of the developed 6 DoF midair haptic device



**Figure 6**

Schematic diagrams of how the device moves and how the presentation force is composed. In each figure, an upper right part is the module 1, and the y-axis of the device faces the front side of this paper. small arrows indicate the presentation force of each vibrator, and large arrows indicate the composed force. (a)–(c) show the composition of the translational force in the direction of the x-axis  $f_x$ , the y-axis  $f_y$ ,

the z-axis  $-f_z$  respectively, (d)–(f) show the composition of the rotational force (torque) around the x-axis  $-\tau_x$ , the y-axis  $-\tau_y$ , the z-axis  $-\tau_z$  respectively



**Figure 7**

An overview of an electrical system for controlling the developed device

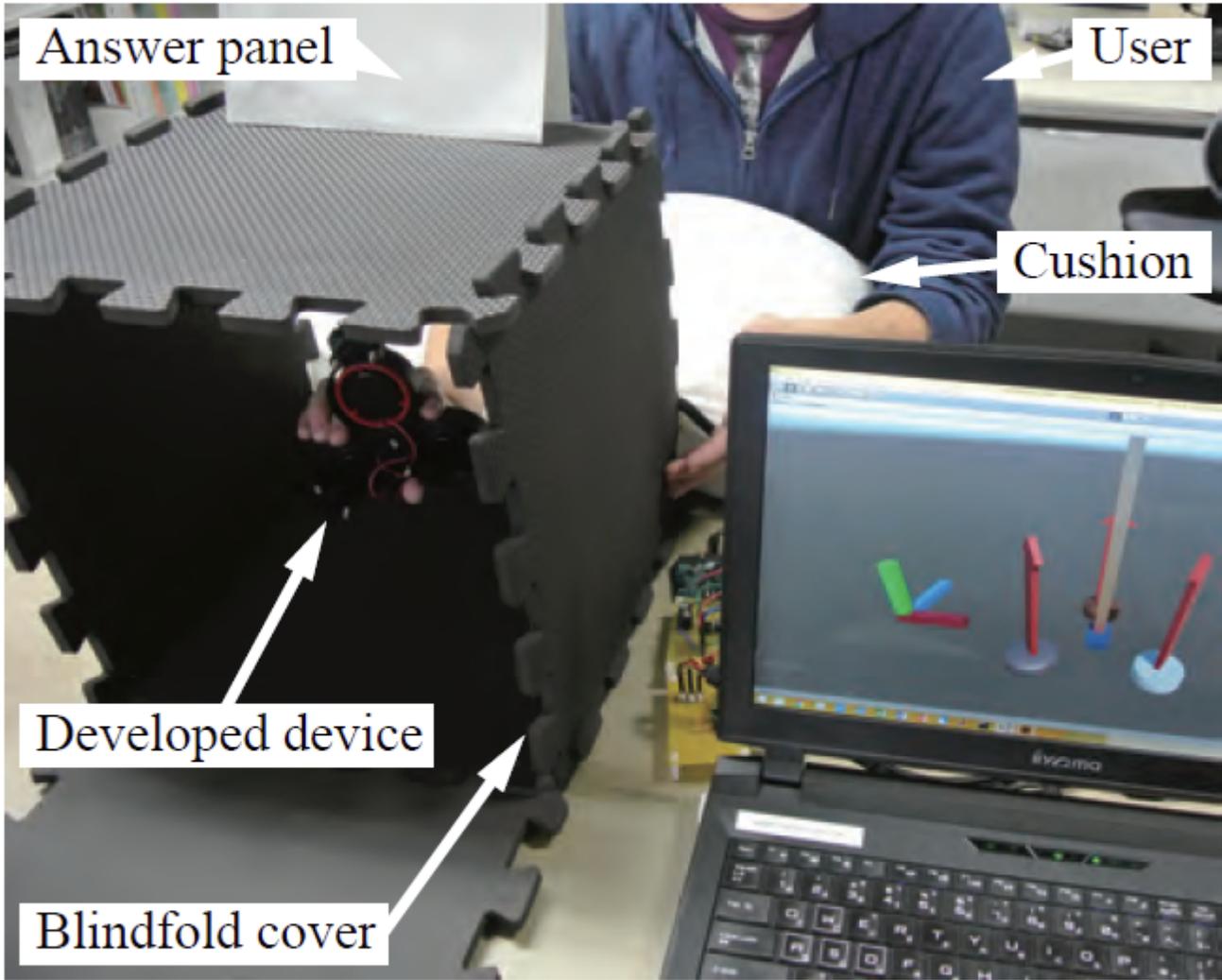


Figure 8

An overview of the user test setup



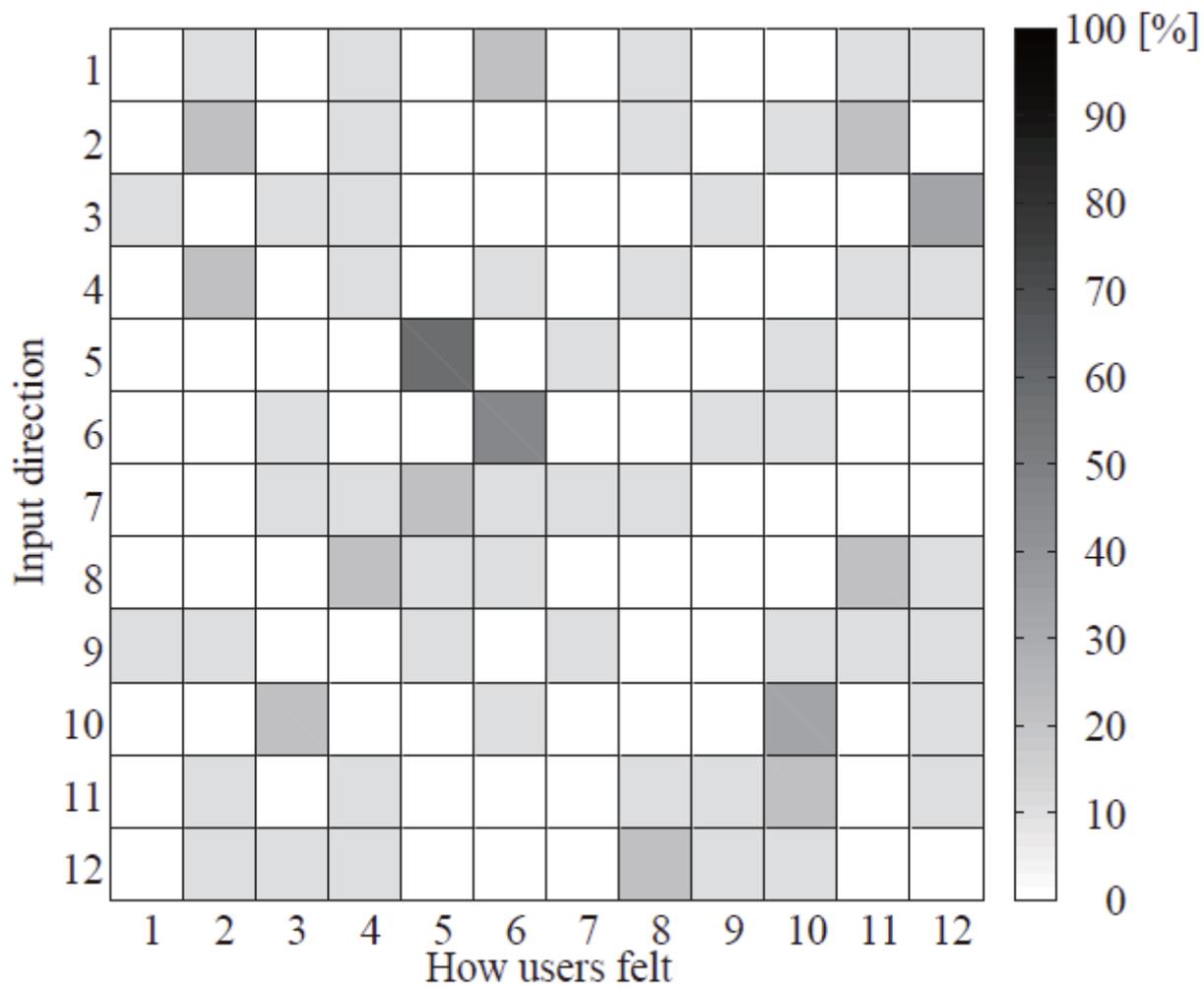
(a)



(b)

**Figure 9**

Two types of experimental devices and how to hold them. Type-1 as shown in (a) is designed so that it can be easily gripped with three fingers by providing a recess in the base of this device, and the modules are separated from each other. Type 2 as shown in (b) is arranged so that each module is closest to each other, and users can directly touch each module by grasping it with the recess of the outer frame



**Figure 10**

A heatmap representation of the user test result with the type-1 devices shown in Table 2

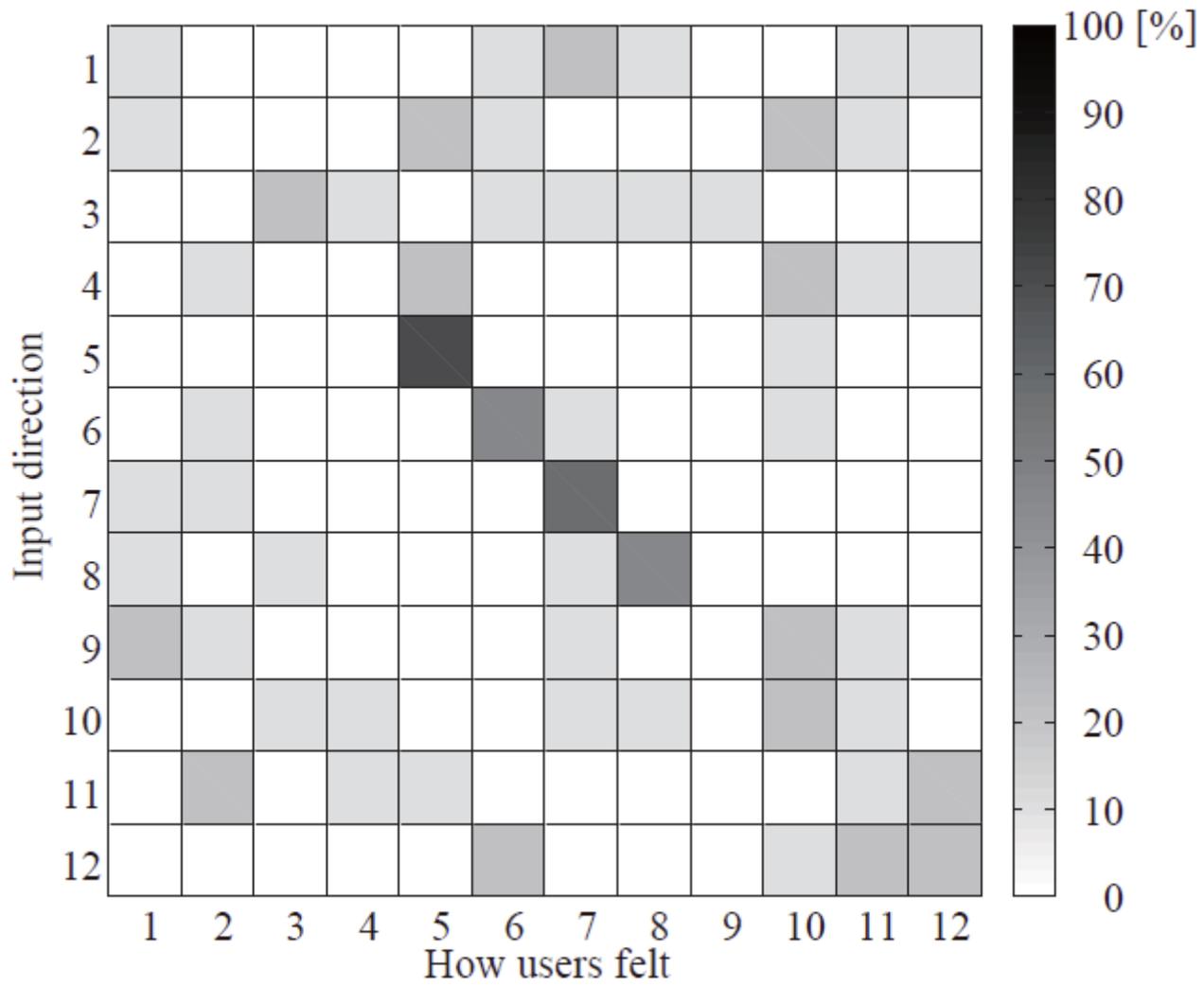


Figure 11

A heatmap representation of the user test result with the type-2 devices shown in Table 3



Figure 12

How to hold the vibrator Vp2 [17], which is thought to contribute to the sensitivity of traction sensation perception