# Preliminary Experiment for Navigation on Tactile Display Using DC Motor

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**Abstract.** In this paper, as a preliminary experiment for walking navigation, conduct experiments of the pseudo force sense using four different waveforms when holding the DC motor with three fingers. In addition, two types of the DC motors with different rotation per minute or RPM and torque, are used to examine an impact of those properties of motors on the pseudo force sense. As a result, it is found that people would feel the pseudo force sense in the direction of the weak rotational acceleration. And There can also be a tendency for people to perceive the pseudo force more easily in the extending direction of the wrist. Moreover, by comparing results from two type of motors with different RPM and torques, it is found that the motor with higher RPM and torque would cause people to feel easily pseudo force.

**Keywords:** Pseudo force sense · DC motor · Walking navigation

## 1 Introduction

In recent years, tactile presentation using vibration has been discussed in the field of human computer interaction. Tomohiro et al. [3] proposed a walking navigation system with traction force illusion which is presented by a mechanism that converts the constant rotation into the translational periodic motion. This mechanism however prevents its device size from downsizing. Yem et al. [5] showed that a pseudo force sense occurs by presenting an asymmetric rotation to a DC motor. By putting two DC motors on the thumb and index finger, people would feel the pseudo force so that the fingers are spreading out or pinching in. Their device uses just only a DC motor so that it could become small enough for people to carry. When it comes back to walking navigation, it is still unclear if the pseudo force sense DC motors manages to display the specific direction. In this manuscript, we focus on walking navigation with a single DC motor and report some properties of the pseudo force sense when people grasp the DC motor with the thumb, index finger and middle one. Specifically two types of DC motors with different velocity of rotation per minute or RPM and torque are used to examine an impact of those types of motors on the pseudo force sense.


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## 2 Previous Work

The previous studies [1,5] discuss a pseudo force sense for the case when a DC motor is attached to the index fingertip in such a way that the output shaft of the motor is held horizontally and orthogonally shown in Fig. 1, and two types of voltage change: the sawtooth wave and the reverse sawtooth wave shown in Fig. 2, are fed. In Fig. 2, the direction in which the gradient of the voltage change is comparatively steep is referred to as the direction of strong rotational acceleration and the direction in which the gradient is comparatively gentle is referred to as the direction of weak rotational acceleration. The result shows that people feel more pseudo force sense in a stronger rotational acceleration direction of the output shaft and they also feel the pseudo force sense easily in the bending direction of the finger. Their system focuses on a way of providing people with the feel of touching and holding an virtual object in a virtual space. This manuscript focuses on a way of providing them with the feel of traction force in a specified direction.

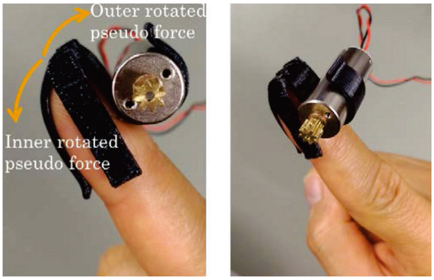


**Fig. 1.** A DC motor attached on the index fingertip. (cited from [5], p. 49)

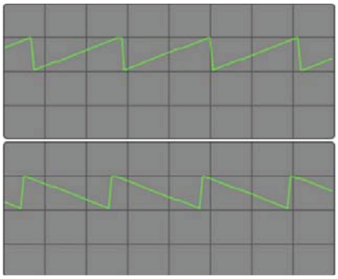

**Fig. 2.** A sawtooth wave (upper) and reverse sawtooth wave (lower). (cited from [1], p. 594)

Another research related to walking navigation using the pseudo force sense is done by Takeshi et al. [2] and it shows that an asymmetric vibration is given on the belly of the finger and if the user grips the vibration speaker then he/she would perceive translational force. Although this device has the advantage of providing translation force to the user, it emits noise due to the vibration speaker. Yuki et al. [6] built a walking navigation system with a hanger reflex. A hanger reflex is a reflection where the head rotates sideways regardless of his intention by attaching the wire hanger to the head so as to sandwich the temporal head. Although their way has the advantage of hands-free device, the device is cumbersome because it needs to be worn around the head. In comparison with these previous devices, the DC motors is compact and small enough to carry, and also works quietly.

# 3 Experiment

The aim of this experiment is to verify three hypotheses about pseudo force sense.

## 3.1 Research Hypothesis

In the previous study [5], a DC motor was attached to the fingertip to investigate pseudo force sense for the purpose of providing people with the feel of grasping objects in a virtual space. This manuscript investigates properties of the pseudo force sense when a DC motor is held with the three fingers, aiming for walking navigation. Holding the similarity with the properties of pseudo force sense mentioned in [5], the following three hypotheses are defined in order to show properties of the pseudo force sense in our approach.

H1: People feel pseudo force sense in the direction of strong rotational acceleration of sawtooth wave.

H2: People perceive easily pseudo force sense in the bending direction of the wrist.

H3: People recognize more easily pseudo force sense for a DC motor with a higher RPM and torque value.

## 3.2 Preparation

In this experiment, two types of DC motors with different RPM and torque, are used to examine an impact of those properties of DC motors on pseudo force sense. Figure 3 shows the DC motors and Table 1 shows their mechanical specifications. Figure 4 shows the user's hand holding the DC motor with three fingers (the thumb, index finger and middle one), and Table 2 shows four different waveforms of voltage (Duty Cycle) change.

**Table 1.** Specifications of two DC motors used in the experiment.

| Item | 3254 E_0 | 3261 E_0 |
|---|---|---|
| Motor type | DC motor with encoder | DC motor with encoder |
| Output power (mechanical) | 590 mW | 2.9 W |
| Maximum speed at rated voltage | 230 RPM | 1080 RPM |
| Rated torque | 200 g-cm | 240 g-cm |
| Stall torque | 1 kg-cm | 1.3 kg-cm |

The left is a DC motor of Phidgets Inc.-3254 E_0 and the right is the other DC motor of Phidgets Inc.-3261 E_0. The right DC motor has higher RPM and torque value than the left one. The rounded part at the top is the weight of 17 g and it is attached to the tip of the output shaft of the DC motor. The weight makes the pseudo force sense more easily recognizable.

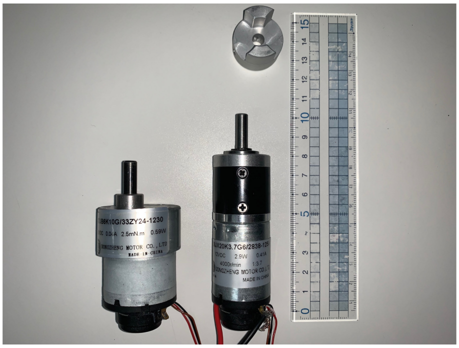

**Fig. 3.** Two types of DC motors (Left:3254 E_0, Right:3261 E_0) and a their weight.

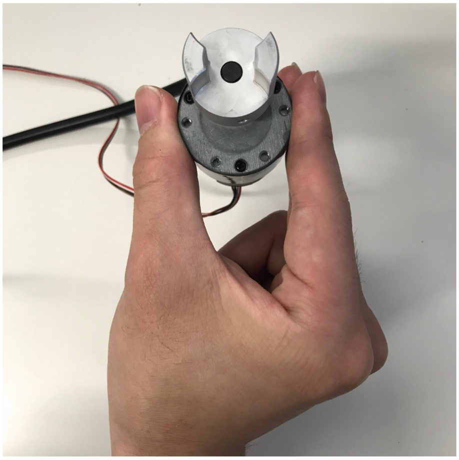

**Fig. 4.** The user is holding a DC motor with the thumb, index finger and middle one.

The direction of rotation (clockwise or counterclockwise) of the shaft of the DC motor is defined as follows. The clockwise direction is the extending direction and the counterclockwise one is the bending direction of the wrist. The DC motor rotates in the clockwise direction when the duty cycle is a positive value and in the counterclockwise direction when the duty cycle is a negative value.

In Table 2, the rotational acceleration means that the rotation speed (Duty Cycle) is added until it reaches 100 or −100 and it changes to the opposite rotational acceleration. The duty cycle of 100 is roughly 230 RPM (3254 E_0) and 1080 RPM (3261 E_0). The performance obtained from 3254E_0 where the corresponding waveform is fed into, is shown in Fig. 5, and those for 3261E_0 is shown in Fig. 6.

For example, the performance in the top left corner in Fig. 5 is obtained when the waveform 1 in Table 2 is fed to the motor 3254E_0. Since the clockwise rotational acceleration is 1000 (%Duty Cycle/s), it reaches from 0 Duty Cycle to

**Table 2.** Four experiment conditions of waveforms presented to the motor.

| Item | Clockwise rotational acceleration (%Duty Cycle/s) | Counterclockwise rotational acceleration (%Duty Cycle/s) |
|---|---|---|
| Waveform 1 (Sawtooth wave) | 1000 | −10000 |
| Waveform 2 (Reverse sawtooth wave) | 10000 | −1000 |
| Waveform 3 | 1000 | −1000 |
| Waveform 4 | 10000 | −10000 |

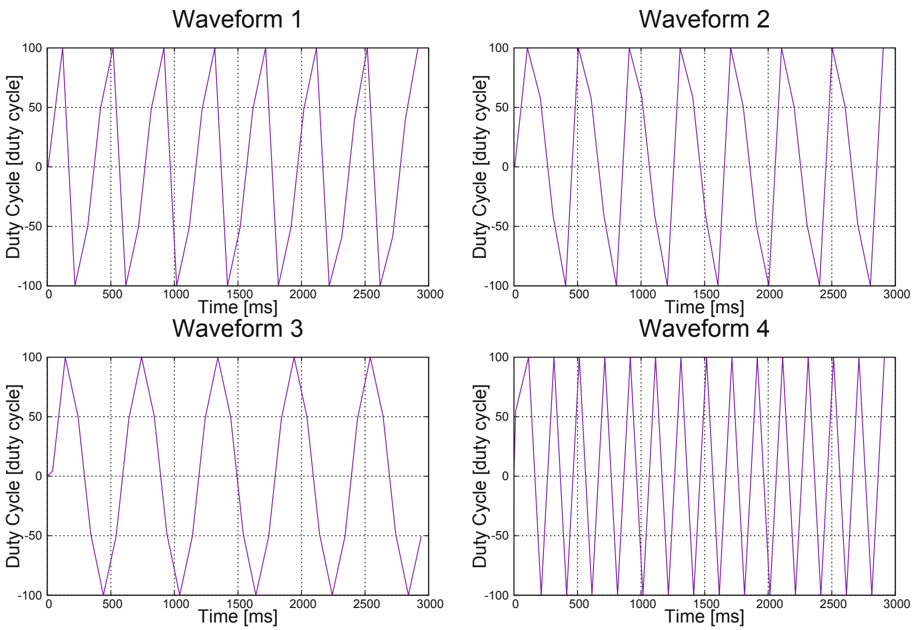


**Fig. 5.** The performance obtained from 3254E_0.

100 Duty Cycle in about 0.1 s and it reaches from 100 Duty Cycle to −100 Duty Cycle in about 0.02 s since the counterclockwise acceleration is −10000 (%Duty Cycle/s).

### 3.3 Subjects

There are seven subjects and they are all students (Male: 6, Female: 1) aged from 21 to 26 years old. They are also all right-handed.

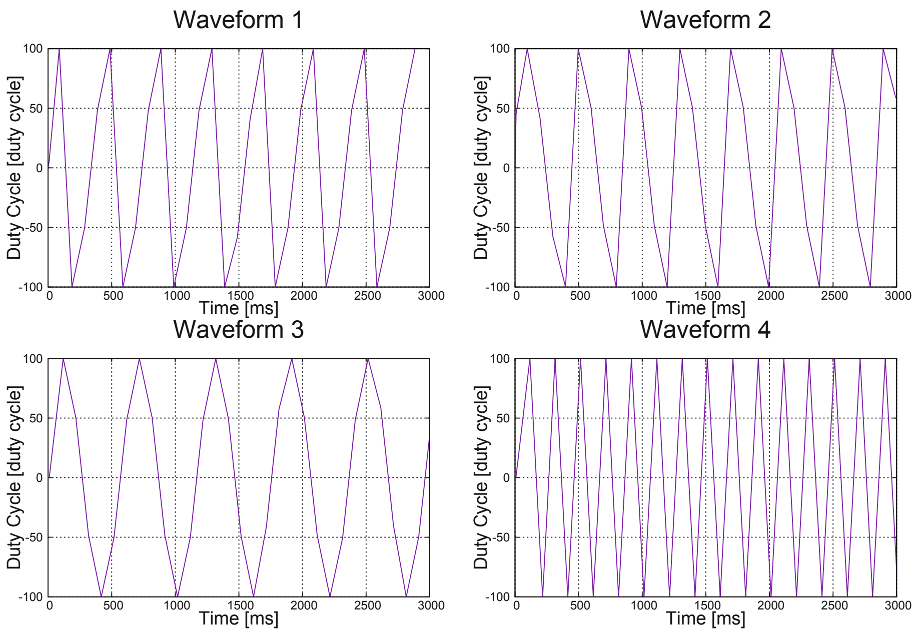


**Fig. 6.** The performance obtained from 3261E_0.

### 3.4 Procedure

They are asked to hold either DC motor (Phidgets Inc.-3254 E_0) or (Phidgets Inc.-3261 E_0) with three fingers of the dominant hand (the thumb finger, index finger and middle finger), so that the output shaft is in the vertical direction. Next, one of the four waveforms is presented to the DC motor with the presentation duration of 15 s. After the presentation, they are asked to answer a questionnaire on pseudo force sense. The questionnaire asks the subject to evaluate the direction in which they have felt the pseudo force sense and the reliability of the answer they made with 11 scales of 0 (low confident) to 10 (high confident). This is repeated with the other three waveforms in a random order.

During the presentation, they are instructed not to contact the desk with the hand holding the DC motor.

During the experiment, the subject puts on a headphone equipped with noise canceling function to block unwanted noise from the DC motor and he/she is instructed not to look directly at the DC motor. As regards unwanted noise, Yamada et al. [4] shows that auditory information alters tactile information, that is people perceive the weight of a thing differently depending on types of collision sounds.

### 3.5 Results

Figure 7 shows the questionnaire results for 3254E_0 and Fig. 8 shows for 3261E_0. They show histograms of direction of pseudo force sense that the subject perceived (left column) and its reliability that he/she answered (right column). From Fig. 7, when the waveform 1 was fed to the DC motor, six subjects felt the pseudo force clockwise, and when the waveform 2 was fed six subjects felt the pseudo force counterclockwise. There could be a tendency for people to feel the pseudo force sense in the direction of weak rotational acceleration. This tendency holds for the other DC motor 3261E_0 shown in Fig. 8. This result does not support the hypothesis H1.

As regards the reliability of the answer, by comparing the waveform 1 and 2, the former seems to be easier for people to perceive the pseudo force because the histogram for the former at the answer "clockwise" is condensed between 7 and 10 while it is scattered over from 3 to 10 for the latter at the answer "counterclockwise". There could also be a tendency for people to perceive the pseudo force more easily in the extending direction of the wrist. This tendency holds for the other DC motor 3261E_0 shown in Fig. 8. This result does not support the hypothesis H2.

The average of histogram values of reliability at the answer "clockwise" for the waveform 1 is 9.00 for 3254E_0 and 9.29 for 3261E_0. The average of histogram values of reliability at the answer "counterclockwise" for the waveform 2 is 7.17 for 3254E_0 and 8.50 for 3261E_0. Therefore the DC motor of 3261E_0 gives the subject much more pseudo force sense. This result supports the hypothesis H3. For the waveforms 3 and 4, their reliability is low to some extent.

### 3.6 Discussions

The hypothesis H1 seems incorrect. The previous study [5] says that people would feel a pseudo force sense in the strong acceleration direction of the sawtooth wave. The result from our experiment is the reverse of the previous one and says that people would feel a pseudo force sense in the weak acceleration direction. It could stem from that this would be influenced by how to hold the DC motor by mounting on the fingertip or holding with the fingers. Since the mass of the fingertip is smaller than the hand size, when the DC motor is attached to the fingertip, the reaction force is large against the acceleration of rotation of the DC motor. However, since the mass of the hand is larger than the fingertip, when the DC motor is held with your fingers, a small reaction force will be added against the acceleration of rotation of the DC motor. It seems that the result was reversed by this.

The hypothesis H2 seems incorrect. The previous study [1] says that people would feel the pseudo force sense easily in the bending direction of the finger. The result from our experiment is the reverse of the previous one and says that people would feel it easily in the extending direction of the wrist. This is also considered to be reversed for the same reason as H1.

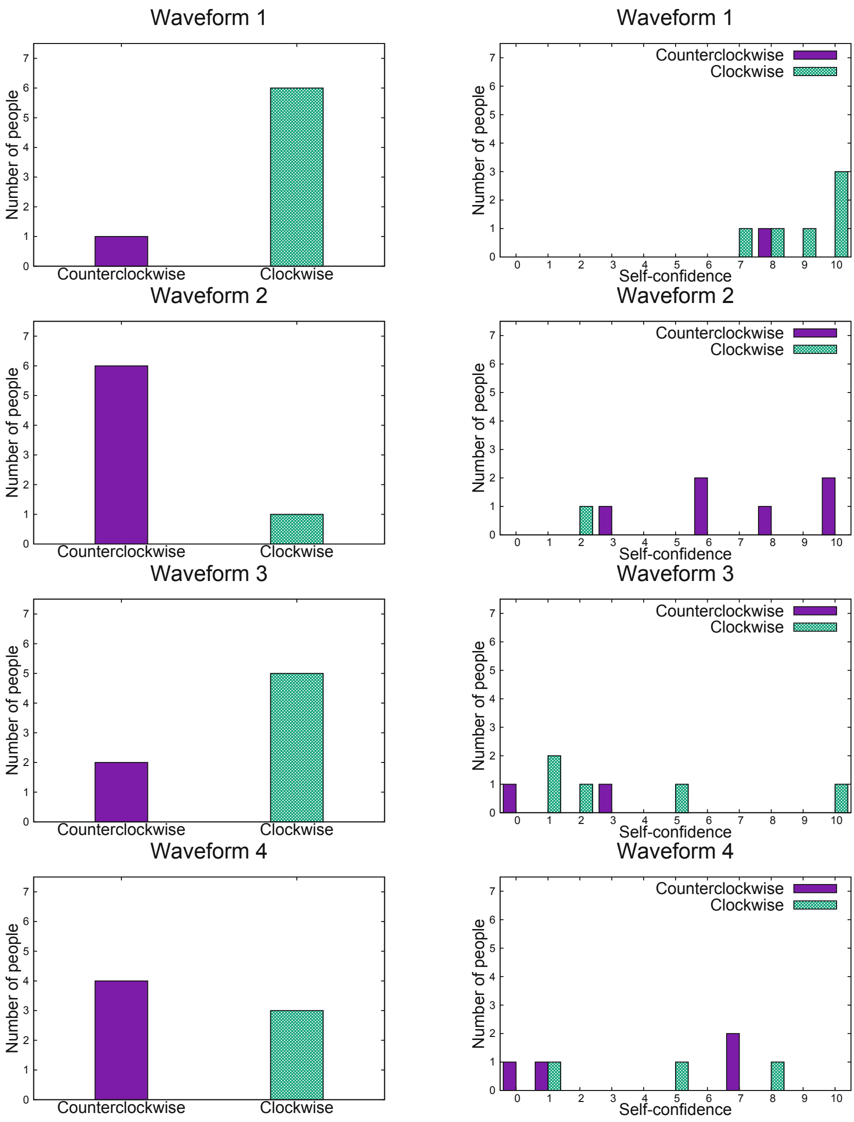


**Fig. 7.** Results from 3254E_0.

The hypothesis H3 seems correct. The hypothesis states that people recognize more easily the pseudo force sense for a DC motor with a higher RPM and torque value. This is because even when the duty cycle reaches 100 or −100, the DC motor with the higher RPM value is rotating much more than the DC motor with the lower RPM value. It needs a stronger reaction force to reverse the rotation of the motor. As a result, the pseudo force sense could be more recognizable for the DC motor with higher RPM and torque values.

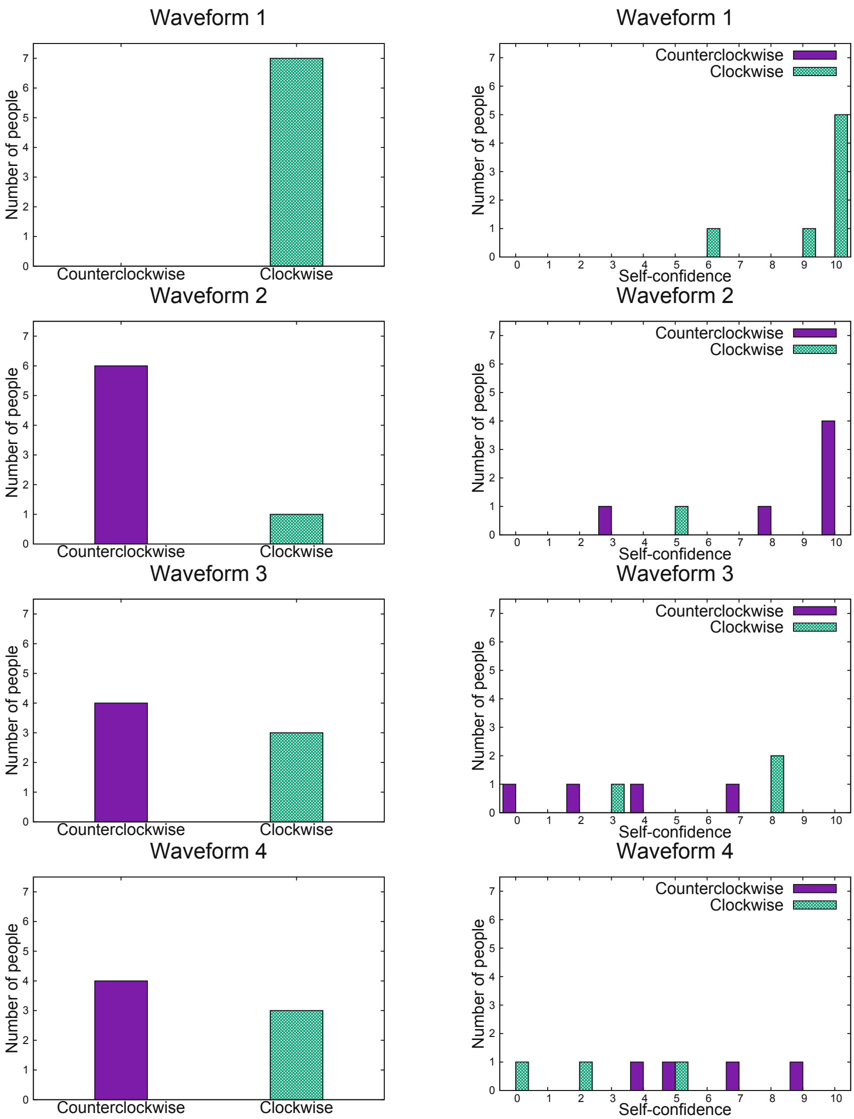


**Fig. 8.** Results from 3261E_0.

## 4 Conclusions

This manuscript discussed properties of pseudo force sense when people hold a DC motor with three fingers of the thumb, index finger and middle finger, and conducted an experiment using two types of DC motors and four different waveforms of voltage change that are fed to the DC motors. As a result, it was found that people would feel the pseudo force sense in the direction of the weak rotational acceleration. And there could also be a tendency for people to perceive the pseudo force more easily in the extending direction of the wrist. Moreover, by comparing the results from two types of motors it was found that the motor with higher RPM and torque would cause people to feel easily pseudo force.

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