Development of Intuitive Force Presentation Method Using Stopper Mechanism for Skill Training

Masamichi Sakaguchi(✉) and Mingoo Lee

Nagoya Institute of Technology, Nagoya, Aichi 466-8555, Japan
saka@nitech.ac.jp

Abstract. In skill training, there are many information and most of skill training depends on watching the skill. However the novice can not acquire the force information by watching the skill. So the trial and error process is required for the skill training. We describes some methods guiding the exerting force of novice to exert the target force at target position. The methods present spring from the target position for the novice exerting target force. Because watching the skill is also important in skill training, the presenting methods intend for presenting the force information without the visual information. The spring element makes the novice actively exerting force. And the stopper and latch element display how much pushing down the spring. The force guiding method use mechanical elements controlled by the brake linear actuator like the spring, stopper and latch. In this paper, the concept and purpose of the method and the validity of the method are described.

Keywords: Skill training · Skill transfer · Force guiding · Force presentation · Robot-mediated training

1 Introduction

There are various kinds of skills. In order to achieve a better performance, motor skills are playing a key role on various kinds of tasks. For instance, skills like piloting, ceramic art, forging, sports and surgical operation need motor skills.

Previous studies of robot-meditated training or teaching use path-following, target-hitting and peg-in-hole task [1]. These tasks are used for evaluating, and most of presented method are assist the purposed task. And these studies concern not exerting the same force and same movement of master of skill but task result. There are various paradigms for training and skill transfer [2,3], force training and learning studies [4,5]. As a study of observation of the sensation of touch, gibson [6] emphasized the difference of touching and being touched and says passive touch plus kinesthesis is insufficient.

In this study, we propose a method, that the trainee gets the guiding information and perceives whether exerting the target force or not. In this paper,

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we introduce the concept of the operating force guiding method using mechanical elements. We made 1-DOF device and evaluated the validity of method. In Sect. 2, the concept and purpose of the proposed method is described. In Sect. 3, device is described. In Sect. 4 experiment procedure and result are described. Finally, discussion and conclusion are described in Sects. 5 and 6. And an example of application is indicated in Sect. 7.

2 Concept and Purpose

The main purpose of this paper is finding a good method for generating environment of matching target force and position. As illustrated in Fig. 1, skill training processes have direct teaching, watching and training. Direct contact teaching, like grabbing tennis racket with novice, has limitation that the body of novice disturbs master's skill. And watching and imitating process can't transfer invisible information like the force information of master. Our aiming application is measuring the master's invisible information without disturbance and presenting the information to the novice. Though the trajectory always depends on the force, there are skills like tennis, which is difficult to measuring the force of master. So the proposed method is used for the skills allowing measuring master's force.

Figure 2 shows the proposed methods for exerting target force at target position. It makes a training environment transferring the force information from the master to the novice. The proposed methods use some mechanical elements. In this methods, presenting a spring which returns the exactly same force of the novice with displacement. The spring make a environment to exert force. Though using a passive elements like spring can't maintain the presenting force by control, the merit of using spring is that we can make a environment for exerting target force actively and the position is stable. When the novice interacts with the training device. The stability of position is only satisfied by equilibrium of force, and spring satisfies equilibrium of force.

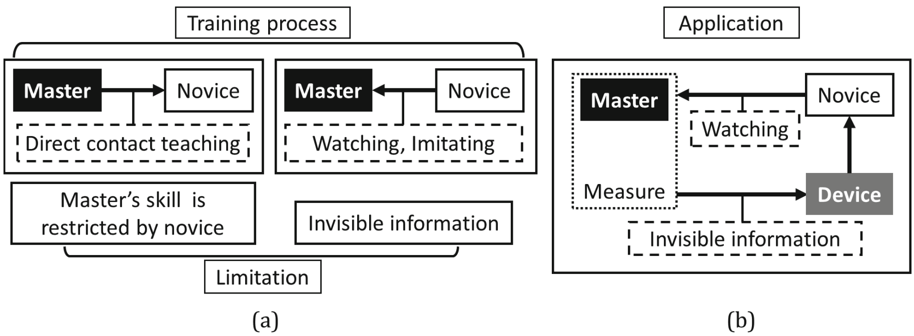


Fig. 1. (a) Training process and limitation of traditional training. (b) Aiming application of presenting method.

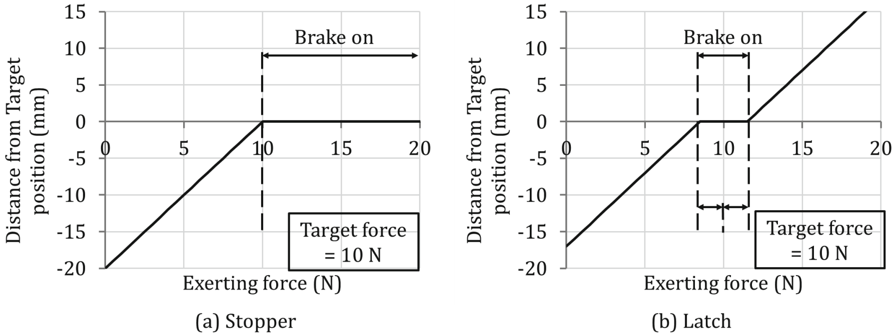


Fig. 2. Methods for exerting target force at target position. (a) Using spring with stopper. novice perceive the target position by the rigid body contact boundary. (b) Using spring with latch. novice perceive the target position by the rigid body contact section

There is two important point for using this method in skill transfer application. The one is non-visual information for force presenting. In the traditional apprentice system, watching the skill is important for learning and imitating the skill. There are many information like the posture, center of gravity and movement of foot. So the methods restricting the eye of the novice like a force status bar can restrict information in skill training. The other is separating the master from the novice. When master teach the novice directly, the skill environment of the master is changed because of the weight of the novice or restriction of movement. By using skill transferring device, the master transfers the skill information on the usual state.

3 Device

The experimental system is composed of a linear guide actuator and a force sensor. The force sensor is placed on the stage of the linear guide, and subjects push down on the top of the force sensor. The device is controlled to present spring by using the position control of a linear guide and the force information. The linear guide (LX26, lead 5 mm, MISUMI) are actuated by the AC servo brake motor (SGMJV-A5ADA2C, 50W, YASKAWA Electric). We use the force sensor with parallel plate structure (A5056). The device presents 1 degree of freedom force information.

4 Experiment

4.1 Experimental Procedure

In this experiment, we confirm that the validity of the mechanical elements guidance. In the process, the novice exerts the target force using the right hand, after remembering the force. 4 methods are tested: no guidance(control), spring-only guidance, spring-stopper guidance, spring-latch guidance. As described in Fig. 3 (a), task for each method has a training phase and a force exerting phase. In the training phase, the visual information for the target force bar is presented. The subject trains exerting the target force and the guidance method with the visual information. In the force exerting phase, the subject wears the blinder and exerts the target force. The subjects are isolated from the noise using white noise and earmuff in both phase. In each phase, the subject exerts force 3 times in 1 min (about 10 s per 1 trial). 1 set has 4 task of each method, randomized order and each subject train 3 set. The target force of each task is the randomized value, and the target force is set over the measured weight of the arm. The age of 8 subjects are twenties, and the are right handed. The subjects have no experience in the device in set 1. Set 1 is conducted a week before set 2, and set 3 is conducted after a week of set 2.

The error value of each trial is calculated from the section of exerted force 5 s in Fig. 3 (b). The exerted force is F_{exert}, the target force is F_{target} F_{error} is the mean of absolute value of $F_{exert} - F_{target}$ during 5 s of exerting force. Each task of a set has 24 data of F_{error}.

4.2 Result

Group 1 is no guidance and spring method, which depends on only human recalling ability, and group 2 is stopper and latch method, which presents information for displacement using break. We compare the two groups. Figure 4 shows the box plot data of the F_{error}. Results of all sets are compared using tukey kramer test. The stopper method is significantly better than the group 1, and the latch method is significantly better than the group 1, except no guidance method in set 3. The F_{error} of no guidance of set 3 is significantly smaller than that of set 1. The Fig. 4 (d) shows that Likert-type evaluation of perception. 1 is difficult to perceive the target force, and 5 is easy to perceive the force.

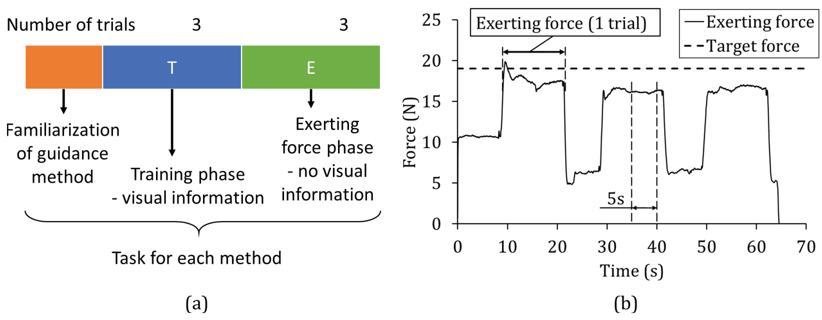


Fig. 3. (a) Structure of task for each method. Training the target force, and exerting force 3 times. (b) A sample of one phase. Force exerting time of a trial is about 10s, and use data of 5 s each trial.

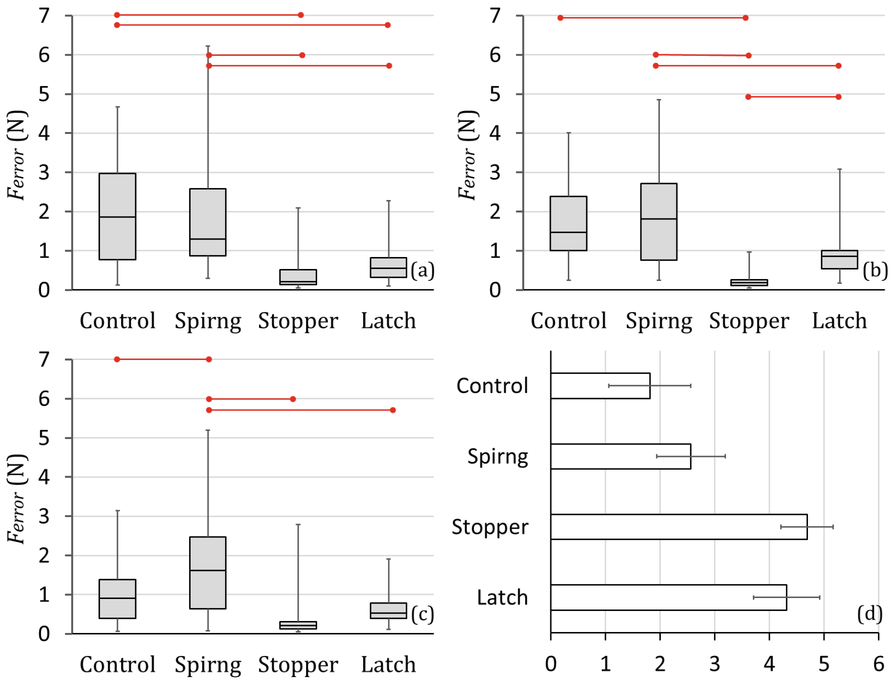
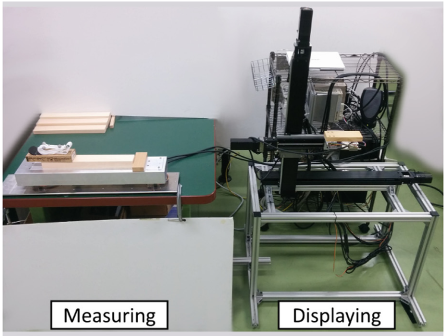


Fig. 4. Box plot of F_{error}. (a) Set 1. (b) Set 2. (c) Set 3. (d) Likert-type evaluation. Lines above the graph show significant diffenrence (tukey-kramer test)

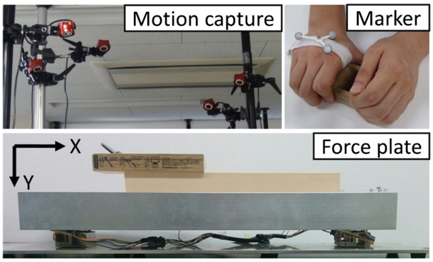
5 Discussion

Using stopper and latch with spring in guidance shows significantly better performance in exerting 1 DOF constant force. Compared to other method, F_{error} of no guidance methods significantly smaller in set 3. This may shows that the no guidance and normal way of learning has faster adaptation speed. Though the novice exerts force more than the target force, the right target position is presented to novice passively. In the process of repeated training, we expect that the novice can get the feedback information of force, and achieve training the target force at the target position.

The presented method is using intuitive and purposive information which is the rigid body contact. Because of the simplicity, the information confuses the operator with the other axis information. So multiple degree of freedom increase complexity of perception and may require visual information. For example, 3-D vision can be used for presenting difference of target force by using the position gap of tool from the right position.



(a) Planing training system



(b) Measuring part

Fig. 5. Wood planing skill training application

6 Conclusion

We have shown force guidance method which generates environment matching the target force at target position. The spring of method satisfies stability of position, and the stopper or latch notify novice the target position. By using the spring, which fixes the relation of force and position, the method make a environment of matching the position and force. The 1-DOF device of the methods guides the constant target force without visual information. 2-DOF force and guiding force with movement experiments are required for future application.

7 Application

From the result, spring-stopper is the most intuitive method in presented methods. By using the method, we develop wood plaining skill training system as shown in Fig. 5. The training system measuring 2DOF position and 2DOF force information. And display 2DOF position and 2DOF force information using spring-stopper method.

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