Demonstrating Naviarm: Augmenting the Learning of Motor Skills using a Backpack-type Robotic Arm System

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ABSTRACT

We present a wearable haptic assistance robotic system for augmented motor learning called Naviarm. This system comprises two robotic arms that are mounted on a user's body and are used to transfer one person's motion to another offline. Naviarm prerecords the arm motion trajectories of an expert via the mounted robotic arms and then plays back these recorded trajectories to share the expert's body motion with a beginner. The Naviarm system is an ungrounded system and provides mobility for the user to conduct a variety of motions. In our demonstration, the user will experience the recording of arm movement with backpack-type robotic arm. Then, the recorded movement will replayed and the user can experience the haptic feedback.

CCS CONCEPTS

• **Human-centered computing → Haptic devices**; *Human computer interaction (HCI)*; • **Computer systems organization →** *Robotics*;

KEYWORDS

Augmented learning; Wearable Device; Motor Learning; Haptics; Robotics;

ACM Reference Format:
Azumi Maekawa, Shota Takahashi, MHD Yamen Saraiji, Sohei Wakisaka, Hiroyasu Iwata, and Masahiko Inami. 2019. Demonstrating Naviarm: Augmenting the Learning of Motor Skills using a Backpack-type Robotic Arm System. In *Augmented Human International Conference 2019 (AH2019), March 11–12, 2019, Reims, France.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3311823.3313868

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AH2019, March 11–12, 2019, Reims, France
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ACM ISBN 978-1-4503-6547-5/19/03.
https://doi.org/10.1145/3311823.3313868

1 INTRODUCTION

In this paper, we propose Naviarm, a haptic assistance system for the augmented learning of motor skills that allows the user to record and play over a relatively wide motion range with the mobility. Naviarm is a backpack-type robotic arm device with seven DoFs per arm (Figure 1). In this system, the motion trajectories of an expert's arms relative to the expert's torso are recorded. The target user of this system is a beginner who aims to learn motor skills from the expert. The user can play back the prerecorded motion trajectories via the robotic arms as a learning support.

Our contributions are summarized as follows.

- We propose a wearable backpack-type haptic device with dual robotic arms.
- We develop a haptic assistance system for augmented learning of motor skills including mobility and a wide range of motion.

2 SYSTEM OVERVIEW

In this section, we present a wearable haptic guidance system for learning arm motor skills. The Naviarm system provides haptic feedback for the wrist position trajectory from experts to beginners using the medium of a wearable robotic arm. Our system for skill learning is composed of backpack robotic arms, haptic-feedback wristbands, and a record-and-replay system.

2.1 Backpack-type Robotic Arms

The hardware design of the backpack dual-arm robot is shown in Figure 1(b). The robot can be carried on the back and has a total weight of 5.75 kg. Each arm has six DoFs and a length of 787 mm. Each joint of the robotic arms is driven by servo-motors (Kondo B3M-SC-1070-A and B3M-SC-1170-A). The maximum torque of the shoulder joint is 15.2 N m, and the resolution is 0.088°. The proposed robotic arm sufficiently covers the range of motion of a human arm [1] and is longer than the average human arm [2]. Therefore, it does not limit the movement of the wearer's arm motion and maintains the DoFs necessary to learn a motor skill. For details on the design of the robotic arm, please refer to [3].

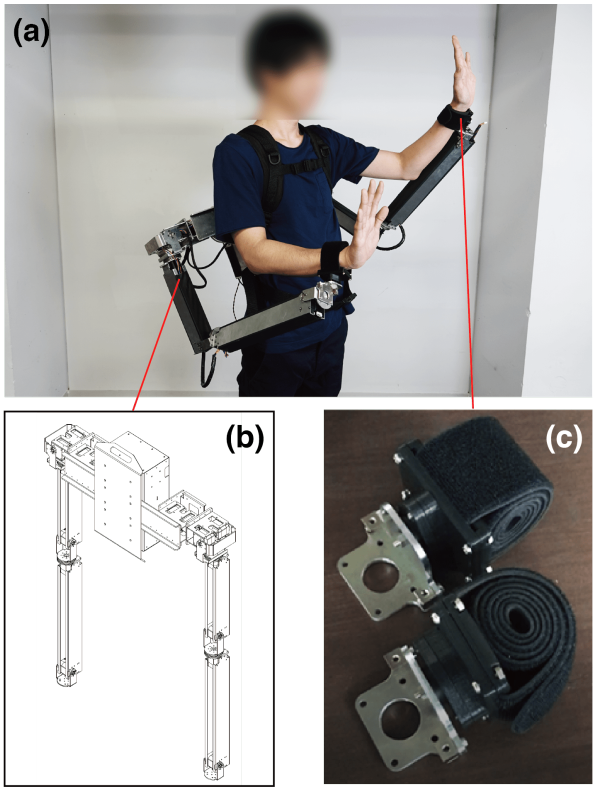

Figure 1: (a) A system overview of the wearable haptic guidance system called Naviarm. (b) The hardware design of the backpack-type robotic arms. (c) The wristband to provide haptic feedback from the robot to the wearer.

2.2 Haptic-Feedback Wristband

We designed a custom wristband that connects the end effector of the robotic arm to the wearer's wrist (Figure 1(c)). This wristband consists of 3D printed parts, bearings, and a cloth band. Its total weight is 91 g, and the cloth band can be applied regardless of body differences. The bearing gives a one-DoF passive joint to the wristband. The proposed number of DoFs was chosen because our feasibility study indicated that a seven-DoF robotic arm including an end effector is suitable for skill extraction from an expert and skill transmission to a beginner.

2.3 Record-and-Replay System

The Naviarm system comprises a recording phase for the expert motion trajectory and a replay phase. First, in the recording phase, an expert carries the robot arms and a haptic-feedback wristband is attached to each of the expert's wrists. When the expert performs an arm motor skill movement, the joint angle data of each robot arm are sequentially recorded as the 3D trajectory of the wrist positions with respect to the wearer's torso. These angle data are translated into wrist position trajectories expressing the sequential motor skill of the expert. The sampling frequency of the system is set to 100 Hz. During the recording phase, the motors of the robotic arms are set to free rotation so that the system does not add extra force to the wearer and the expert can perform the motor skill performance in the same way as when the robotic arm is not worn.

In the replay phase, the robotic arm is set to active control, and therefore, all motors are activated. The arms move the beginner's wrists according to the sequential angle data of the recorded expert motor skill movement. In this phase, the recorded data are also queried at 100 Hz; therefore, the temporal resolution of the motion is 0.01 sec. At that time, a beginner can learn the sequential motion trajectory of the expert while a directed force is applied to the wrist via the wristband.

2.4 Naviarm System

Here, we present the main characteristics of the developed backpack-type robotic arm system for learning motor skills. First, the proposed Naviarm system can directly teach the temporal aspects of a motor skill, e.g., timing, pattern, or sequence, via the dual-robotic arms. During the acquisition of a motor skill, it is challenging to learn sequential motor skills as a structure that smoothly connects individual motor skills [4]. However, the Naviarm record-and-replay system first assists in conveying an expert's motor skills without sequential changes. Therefore, the wearer is able to learn a sequential motor skill with motions involving both entire upper limbs via direct haptic feedback. Then, the proposed backpack-type robotic arms have higher mobility compared to grounded apparatuses. Mobility is essential for training a wide range of upper limb motor skills while involving the movement of a user's legs, for example, for activities such as dancing and sports. Therefore, the mobility of Naviarm is an important characteristic in terms of the variety of applicable motor skills. Finally, Naviarm can be used for learning motor skills both online and offline. As an example of online use, using Naviarm, one teacher would be able to teach sequential dance movements to numerous students in real time.

3 CONCLUSIONS

In this paper, we proposed Naviarm, a novel haptic feedback system for augmenting the learning of motor skills. The system uses backpack-type robotic arms to transmit haptic information and can handle a larger range of motion compared to previous haptic guidance systems.

ACKNOWLEDGMENTS

We would like to thank G. Ganesh, M. Kitazaki, M. Sugimoto, and Y. Miyawaki for useful advice. This project was supported by JST ERATO Grant Number JPM-JER1701, Japan.

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