Low-Latency Motion Transfer with Electromagnetic Actuation for Joint Action

Daisuke Tajima
Sony Computer Science Laboratories, Inc.
Japan
daisuke.tajima@csl.sony.co.jp

Taku Tanichi
Sony Computer Science Laboratories, Inc.
Keio University Graduate School of Media Design
Japan
tanichi@kmd.keio.ac.jp

Mohammad H. Shehata
California Institute of Technology
USA
Toyohashi University of Technology
Japan
shehata@caltech.edu

Shunichi Kasahara
Sony Computer Science Laboratories, Inc.
Japan
kasahara@csl.sony.co.jp

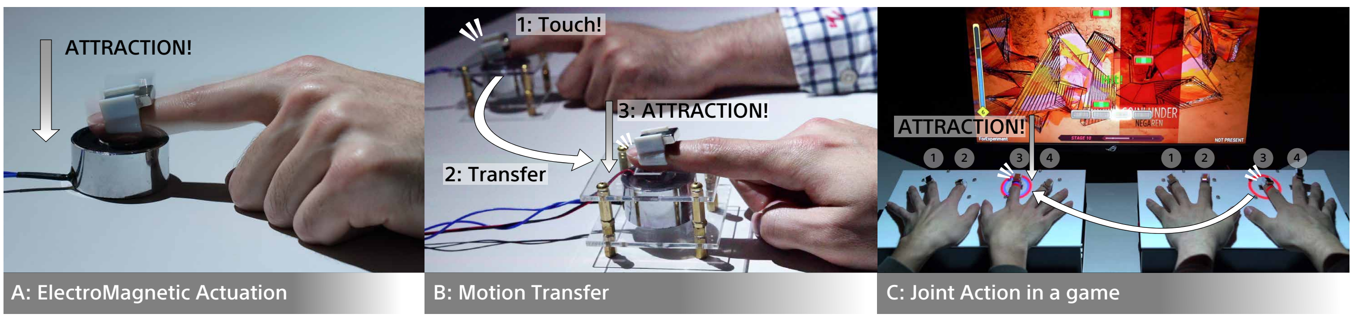

Figure 1: EMAS: ElectoMagnetic Actuation System. A) Attracting a neodymium magnet of the finger attachment by the electromagnet makes an actuation of the user's finger. B) The combination of the user's action and electromagnetic actuation enables the motion transfer from one user to another. C) Integrating the four electromagnets as an EMAS allows the system to orchestrate the user's joint action in a task.

ABSTRACT

Joint action, performing a task together by multiple people, can be beneficial in transferring the embodied skill, establishing physical relationships, engaging multiple people, and completing the task more effectively. To facilitate real-time joint bodily action, we introduce a low-latency motion transfer system (total latency: $22.9 \pm 2.0ms$, finger attraction latency: $13.7 \pm 2.1ms$) using electromagnetic actuation, which allows them to share their instantaneous actions, such as pressing the button with their fingers. Our system can change the type of motion transfer at both the direction of the transfer between users (mono- or bi-direction) and the input logic ("AND" or "OR") based on the users' input. We will discuss its potential as a computer-assisted joint action and the possibility that the computer system orchestrates the joint action between the users or the user and the computer.

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1 INTRODUCTION

Joint action [Vesper et al. 2016], performing a task with other people, often occurs in many situations; transferring large furniture by lifting it up with two people, teaching how to paint by moving the student's hand, removing one block at a time from a tower constructed of many blocks, operating a machine, playing a video game, etc. The computer assistance to foster such an inter-personal joint action would be beneficial to improve the effectiveness, engagement, and interest of the completing task.

What kind of computer assistance is beneficial for this joint action? In general, in joint action, people rely on visual, auditory, and haptic signals to synchronize with other people. We here propose the low latency motion transfer system that can control the patterns of the haptic cues for the joint action, which is directly actuation

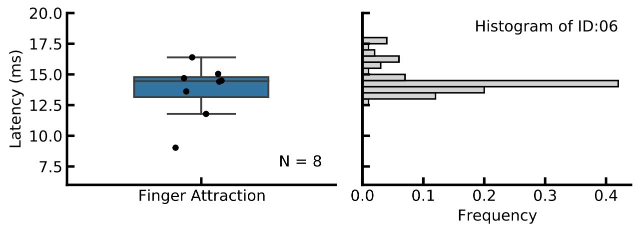

Figure 2: Finger attraction latency from the activation of the electromagnet to the finger-driven button press.

of the users' fingers without the electric sensation [Kasahara et al. 2019] nor physical restraint [Marconi et al. 2019].

2 ELECTROMAGNETIC ACTUATION SYSTEM

The ElectroMagnetic Actuation System (EMAS) is composed of mainly two parts; the finger attachment with the neodymium magnet and the electromagnet inside the box. The finger attachment can be attached to any fingers of users, such as the index finger and middle finger in both hands, in total four fingers for one user (Fig. 1 C). The electromagnet is placed under the input buttons. By attracting and repulsing the user's fingers using the electromagnet, the system can induce the user input behavior, like pressing a button. The attraction power is approx. 2.0 N, which is enough to move the user's finger, yet users still can resist its actuation. Fig. 2 shows the trend of the actuation latency (ave. $13.7 \pm 2.1 ms$); the duration from electromagnet activation to finger-driven button pressing. Total latency of motion transfer from the user A's button input to the user B's button input was $22.9 \pm 2.0 ms$. Given the latency of other actuation methods such as approx. 40 ms with electrical muscle stimulation [Kasahara et al. 2019], and approx. $200 ms$ with exoskeleton [Marconi et al. 2019], our electromagnetic actuation is clearly faster.

With our low-latency actuation, our system enables rapid motion transfer inter-personally by triggering fingers actuation from other user's key input(Fig. 1 B). EMAS system is also compatible with **remote motion transfer** over the Internet, as well as with a physically co-located wired configuration.

3 ORCHESTRATING JOINT ACTIONS

With leveraging rapid actuation of finger and inter connectivity of the system, EMAS can orchestrate the user's joint action with four patterns; the combination of the direction (mono / bi) and input logic (AND / OR) as depicted in Fig 3.

A: Mono-direction / OR-input
The system transfers the user's motion to another and allows both users' input. This operation can evoke the experience where the user assists another's action through the system.

B: Mono-direction / AND-input
The system transfers the user's motion, but only accepts the input when both users press the buttons. This operation allows the user to let another user be under control just like the "Marionette".

C: Mono-direction / AND-input
The system exchanges the motion of both users and accepts input from both users individually. This operation is expected to allow users to collaborate with each other using the motor or/and haptic cue through their actual fingers.

D: Bi-direction / AND-input
The system exchanges the motion of the user's fingers but only accepts the input when both users press simultaneously. If the user disagrees with the input of another user, the user can resist the EMAS attraction, resulting in total rejection of the input. Thus, this operation requires users to make a consensus on their input.

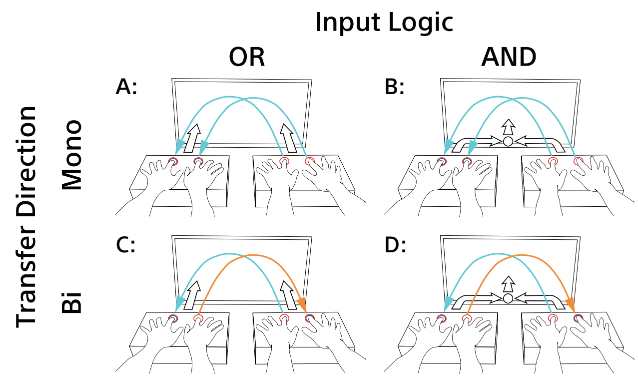

Figure 3: A: Schematic representations of the system operations based on the motion transfer types and input logic

4 CONCLUSION

We demonstrated the facilitation of joint action using low-latency electromagnetic motion transfer system. From the perspective of feeling of control with the computer system assistance [Tajima et al. 2022], we believe that our low-latency motion transfer between users will allow us to investigate possible scenarios of joint action in real time even over distance.

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