MetaLimbs: Metamorphosis for Multiple Arms Interaction using Artificial Limbs

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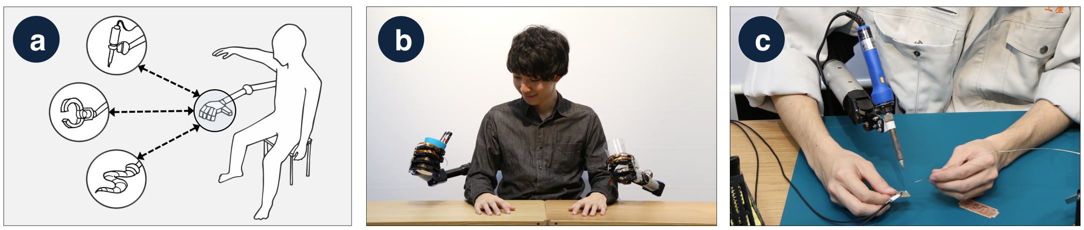

Figure 1: (a) Concept of adding extra limbs with the ability to customize them. (b) MetaLimbs augmenting daily activities. (c) Using a soldering tool as replacement of the artificial hand.

ABSTRACT

If we could have the capability to edit or customize our body scheme by technology, could our abilities and activities be enhanced? This research proposes a novel interaction to alternate body scheme using artificial limbs substitution metamorphosis. In this work, two additional robotic arms are added to user's body, and are manipulated by legs movement. Limbs control is achieved using two sets of tracking systems: global motion tracking of legs using an optical tracker and local motion tracking for manipulation purposes using socks type device. These data are mapped into artificial limbs' arms, hands and fingers motion. Lastly, force feedback is provided to the feet and mapped to manipulator's touch sensors.

CCS CONCEPTS

•Human-centered computing →Interaction devices; •Computer systems organization →*Robotic control;*

KEYWORDS

Body scheme alternation, Limbs expansion, mapping & control

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1 INTRODUCTION

Human bodies are magnificently capable to achieve complex tasks, and our arms and hands have a large number of degrees of freedom allowing us to use them as general purpose tools. However, human bodies are also limited in terms of physical capabilities and limbs number. The former limitation has been addressed by the evolution of tool design, which has became an extension of our bodies abilities. The latter one, however, has been an open research question for a long time. If we could have the capability to edit or customize our body scheme by, for example, adding more limbs with new functions while maintaining voluntary control, then our capabilities and activities can be enhanced. By recent advances in science and technology, it is gradually becoming to realize some human augmentation with wearable, human-centered or robotic device.

MetaLimbs, a multiple arms interaction system with high degrees of freedom limbs motion and control is proposed. Fig 1(a) shows the concept of MetaLimbs in which the arms can be customized to different tools and functions. In this system, additional two robotic arms are added to user's body and are mapped to his feet motion. User's foot positional motion controls the corresponding robotic arm position, and toes controls hand fingers gripping. A custom data shoe was designed to capture toes bending, and is used to provide control data to the robotic fingers. Using limb substitution approach, it is possible to map one limb with another while maintaining high degrees of motion for the new limb. Fig 1(b) shows MetaLimbs system augmenting daily activity.

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2 RELATED WORKS

Previous work in the area of prosthetic and artificial limbs have been largely studied mainly for medical purposes to substitute missing limbs for people with disabilities and for rehabilitation, but not as body functions enhancement and augmentation. Stelarc [Kac 1997] was one of the earliest art performers who investigated the effect of adding a third hand to augment his body functions. For limb augmentation control, two main approaches were addressed previously: autonomous limbs, and motion-driven limbs. Parietti et al.[Parietti and Asada 2014] proposed wearable robotic arms to support user's work in an autonomous manner for application specific use-cases. Leigh et al.[Leigh and Maes 2016] proposed additional joint interface which is programmable and controlled by userfis electromyography (EMG). Due to the autonomous behavior of these arms or joints and lack of voluntary control, this approach is not suitable as general purpose limbs.

Prattichizzo et al.[Prattichizzo et al. 2014] proposed adding an extra finger to the hand, and using a data glove trained to certain hand postures, the user can control this artificial finger enhancing gripping functions for large objects. Wu et al.[Wu and Asada 2014] also proposed supernumerary robotic fingers, which add two extra robotic fingers to support tasks using only one hand, and using postural synergies, artificial fingers' motion are driven from user's fingers. Both methods use motion-driven limb control, however due to motion coupling between the artificial limbs and user's limb motion, the actual operating space is reduced and limited to specific applications. In order to provide a true voluntary artificial limb motion, we propose to use limb substitution based approach in which the legs are mapped to artificial arms. Legs and feet are used as input modality for artificial limb control. Previous work addressed feet interaction for computer interaction purposes [Simeone et al. 2014; Velloso et al. 2015], but in this work we are addressing feet motion for limb-to-limb kinesthetic mapping purpose.

3 SYSTEM DESCRIPTION

The proposed system consists mainly of two parts: limb postural tracking system and two mounted robotic arms as shown in Fig 2.

The postural tracking system is responsible to generate arms/tool motion trajectory driven by leg/foot local and global tracking. Regarding local tracking of foot toes, wearable tracking device similar to socks were developed to capture the posture of the hallux and the rest of the toes for each foot using two built-in bending sensors.

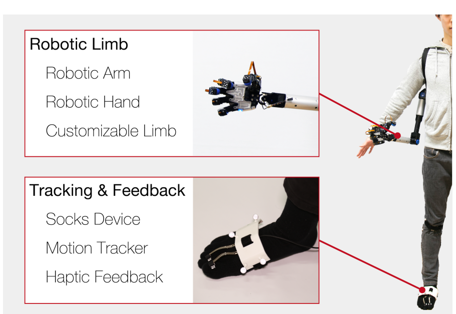

Figure 2: System overview: artificial limb, leg tracking system, and haptic feedback system.

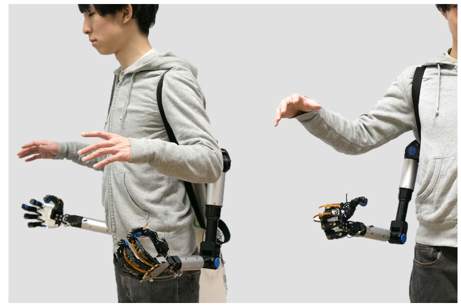

Figure 3: Arms mounted on user's back

Measured data of the sensors are used to generate fingers motion and gripping of the robotic hand or tool. Global position tracking uses an optical tracking systems, and a set of markers are placed on user's knees and feet. Each marker is captured by the tracking module, and these position/rotation data are used to calculate the position and orientation of the robotic arm end effector (the tool or hand).

The mounted robotic arms are design with 7 degrees of freedom (DOF) for each arm with a removable manipulator, such as a hand or a tool. This design methodology allows wide variety of customizations for the new limbs. In our experiments, we used a humanoid robotic hand with 22 DOF for fingers. The manipulator contains a force sensor that detects touch and grasping forces, and using these data, a force feedback belt is triggered on the foot in correlation to force magnitude. For the initial evaluations of this interaction, we first conducted a preliminary study using a simulated VR environment in which the user can see both his/her hands and the artificial hands, and mapping parameters were set[Sasaki et al. 2016]. After the evaluation of the interaction, the robotic arms system were used for physical manipulation. Arms position can be adjusted along user's spin axis, allowing to perform new forms of body schemes as shown in Fig 3.

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