MetaLimbs: Multiple Arms Interaction Metamorphism

Tomoya Sasaki, MHD Yamen Saraiji, Charith Lasantha Fernando,
Kouta Minamizawa, Masahiko Inami
Keio University Graduate School of Media Design
The University of Tokyo
{t.sasaki,yamen,chairth,kouta}@kmd.keio.ac.jp,inami@inami.info

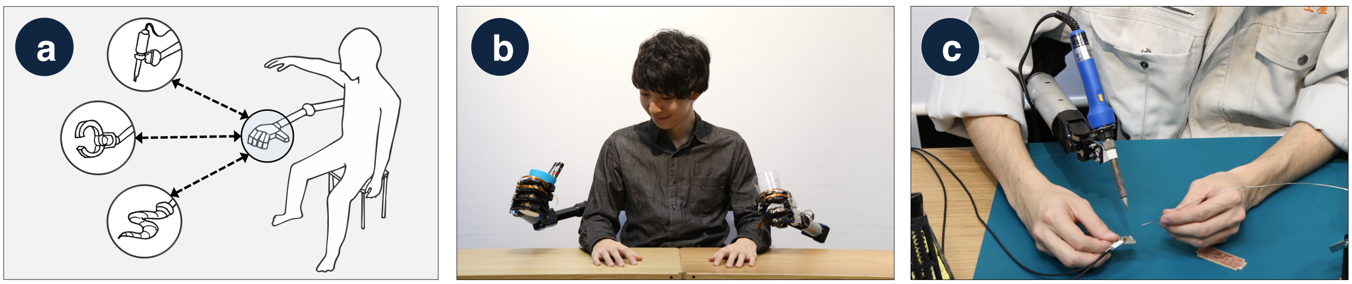

Figure 1: (a) Concept of adding extra limbs with the ability to customize them. (b) Metalimbs augmenting daily activities. (c) Using a soldering tool as replacement of the artificial hand.

ABSTRACT

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 substituted with the legs. Using this arms/legs substitution, arms count is expanded to four arms in total with voluntary control using legs motion mapping. Limbs control is achieved by tracking the global motion of legs and feet relative to torso, as well as local motion of toes. These data are mapped to the artificial limbs' arms/hands motion and fingers gripping. Lastly, force feedback is added to the feet and mapped to manipulator's touch sensors. Using this system, it is possible to perform difficult tasks normal body can not achieve alone, such as holding many objects simultaneously.

CCS CONCEPTS

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

KEYWORDS

Body scheme alternation, Limbs expansion, mapping & control

ACM Reference format:
Tomoya Sasaki, MHD Yamen Saraiji, Charith Lasantha Fernando, Kouta Minamizawa, Masahiko Inami. 2017. MetaLimbs: Multiple Arms Interaction Metamorphism. In *Proceedings of SIGGRAPH '17 Emerging Technologies, Los Angeles, CA, USA, July 30 - August 03, 2017,* 2 pages.
DOI: http://dx.doi.org/10.1145/3084822.3084837

DOI: http://dx.doi.org/10.1145/3084822.3084837

1 INTRODUCTION

Human bodies are magnificently capable to achieve complex tasks, and our arms and hands have large number of degrees of freedom allowing us using 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 long time. If we could have the capability to 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.

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. Due to the autonomous behavior of these arms 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

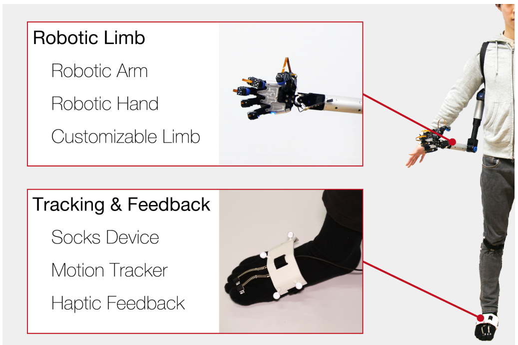

Figure 2: System overview: artificial limb, leg tracking system, and haptic feedback system.

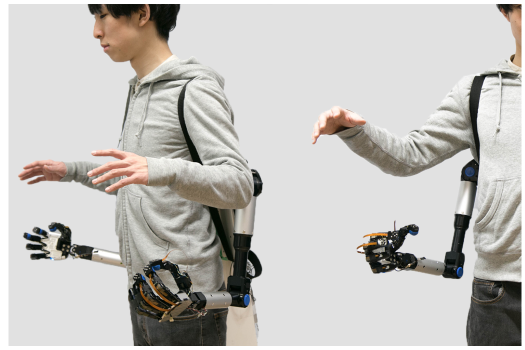

Figure 3: Arms mounted on user's back

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.

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.

2 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 and mapping system is responsible to generate arms/tool motion trajectory driven by leg/foot local and global tracking. Local tracking of foot toes was done using wearable tracking shoes which capture the bending amount for the hallux and the rest of the toes for each foot. The global position tracking was done using optical tracking markers mounted on the knees and feet. For the initial evaluations of this interaction, we first conducted an evaluation using a simulated VR environment in which the user can see both his 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.

The mounted robotic arms are design with 7 degrees of freedom (DOF) for each arm, and an attachable 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 this data a force feedback belt is triggered on the foot in correlation to force magnitude. Arms position can be adjusted along user's spin axis, allowing to perform new forms of body schemes as shown in Fig 3.

3 USER EXPERIENCE

At SIGGRAPH 2017 Emerging Technology exhibition we will demonstrate MetaLimbs system with the proposed two artificial arms and limb mapping interaction. The arms will provide force feedback using a haptic interface attached to attendee's feet. The users will experience new body form (4 arms experience), also are capable to customize arms positioning along their back. Attendees can select the type of manipulator attached to the arm other than the humanoid hand, such as a soldering tool as shown in Fig 1(c), or a music instrument device. Using MetaLimbs, attendees can perform new sort of interaction with other attendees such as hand shaking with many people at the same time. Also to perform difficult tasks such as holding several objects or large objects at the same time that a normal person can not perform.

ACKNOWLEDGEMENTS

This project is supported by JSPS KAKENHI Grant Number 15H01701.

REFERENCES

Eduardo Kac. 1997. Foundation and development of robotic art. *Art Journal* 56, 3 (1997), 60–67.

Federico Parietti and H Harry Asada. 2014. Supernumerary robotic limbs for aircraft fuselage assembly: body stabilization and guidance by bracing. In *2014 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 1176–1183.

Domenico Prattichizzo, Monica Malvezzi, Irfan Hussain, and Gionata Salvietti. 2014. The sixth-finger: a modular extra-finger to enhance human hand capabilities. In *The 23rd IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 993–998.

Tomoya Sasaki, MHD Yamen Saraiji, Kouta Minamizawa, Michiteru Kitazaki, and Masahiko Inami. 2016. Changing body ownership using visual metamorphosis. In *Proceedings of the 2016 Virtual Reality International Conference*. ACM, 33.

Adalberto L Simeone, Eduardo Velloso, Jason Alexander, and Hans Gellersen. 2014. Feet movement in desktop 3D interaction. In *3D User Interfaces (3DUI), 2014 IEEE Symposium on*. IEEE, 71–74.

Eduardo Velloso, Dominik Schmidt, Jason Alexander, Hans Gellersen, and Andreas Bulling. 2015. The feet in human–computer interaction: a survey of foot-based interaction. *ACM Computing Surveys (CSUR)* 48, 2 (2015), 21.

Faye Wu and Harry Asada. 2014. Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers. In *Proceedings of Robotics: Science and Systems*. Berkeley, USA.