Superception: Exploring new 'Self' in the integration of humans and computers

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ABSTRACT

With the emergence of computer technologies, computers are no longer just tools of human, but are deeply intervening in our bodies and behavior. When humans integrate with computers and acquire abilities and different bodies beyond what we have, to what extent are we ourselves? Through my research framework "Superception" for extending and transforming human perception and cognition using computer technology, we are investigating how the "self" can be shaped when humans and computers integrate. In this talk, I would like to explore what the "self" will be like when computers and humans integrate through three research directions; 1) Self in Human computer integration, 2) Beyond one mind one body, and 3) Contours of the self. Lastly, I would like to discuss the potential agenda of science in human-computer integration through circulating perceptual research and experience design.

INTRODUCTION

When humans and computers integrate, to what extent are we ourselves? With the emergence of computer technologies, computers are no longer just tools of human, but are deeply intervening in our bodies and behavior. When humans integrate with computers and acquire abilities and different bodies beyond what we have, to what extent are we ourselves? Through my research framework "Superception" for extending and transforming human perception and cognition using computer technology, we are investigating how the "self" can be shaped when humans and computers merge.

2. Self in Human computer integration

With cybernetics technology, it is becoming possible to assist, augment, and extend human motoric and intellectual abilities. However, in order to realize a state where technology is truly harmonized with humans, we must consider the "self" of the user, i.e., to what extent are we ourselves? Even if we were to implement abilities that greatly surpass those of humans, or even if we were to acquire a body that is different from our own, we can not state that humans and technology have mutually adapted to each other unless we feel them as our own perceptually and cognitively. This is why we believe that elucidating and designing the integration of humans and computers with "self" is an important research agenda.

2.2 Preemptive Action

As the first example of research about Self in Human computer integration, We enable preemptive force-feedback systems to speed up human reaction time without fully compromising the user's sense of agency [1]. Typically these interfaces actuate by means of electrical muscle stimulation (EMS) or mechanical actuators; they preemptively move the user to perform a task, such as to improve movement performance (e.g., EMS-assisted drumming). Unfortunately, when using preemptive force-feedback users do not feel in control and loose their sense of agency. We address this by actuating the user's body, using EMS, within a particular time window (160 ms after visual stimulus), which we found to speed up reaction time by 80 ms in our first study. With this preemptive timing, when the user and system move congruently, the user feels that they initiated the motion, yet their reaction time is faster than usual. As our second study demonstrated, this timing significantly increased agency when compared to the current practice in EMS-based devices. We conclude by illustrating, using examples from the HCI literature, how to leverage our findings to provide more agency to automated haptic interfaces.

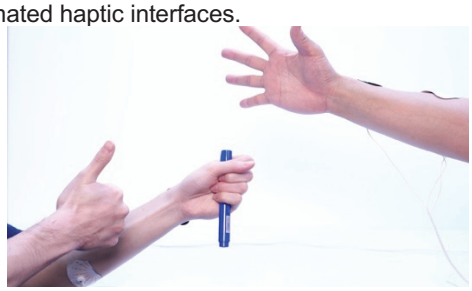

Fig. 1 Preemptive Action demonstration

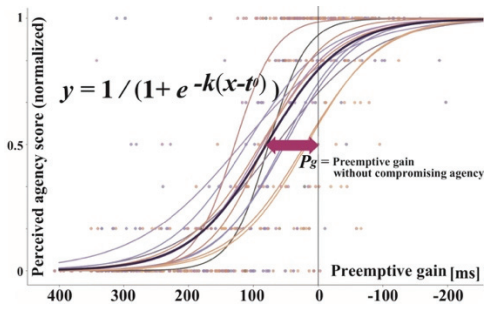

Fig. 2 The sense of agency can be preserved even with EMS-based speeding up of actions.

2.3 Whose touch is this

In addition to Preemptive Action, we also explore more complete situation where human and computer performs choice task [2]. Force-feedback interfaces actuate the user's to touch involuntarily (using exoskeletons or electrical muscle stimulation); we refer to this as computer-driven touch. Unfortunately, forcing users to touch causes a loss of their sense of agency. While we found that delaying the timing of computer-driven touch preserves agency, they only considered the naive case when user-driven touch is aligned with computer-driven touch. We argue this is unlikely as it assumes we can perfectly predict user-touches. But, what about all the remainder situations: when the haptics forces the user into an outcome they did not intend or assists the user in an outcome they would not achieve alone? We unveil, via an experiment, what happens in these novel situations. From our findings, we synthesize a framework that enables researchers of digital-touch systems to trade-off between haptic-assistance vs. sense-of-agency.

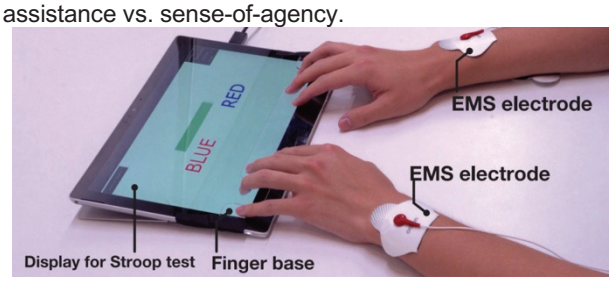

Fig. 3 Choice task experiment with both-hand EMS.

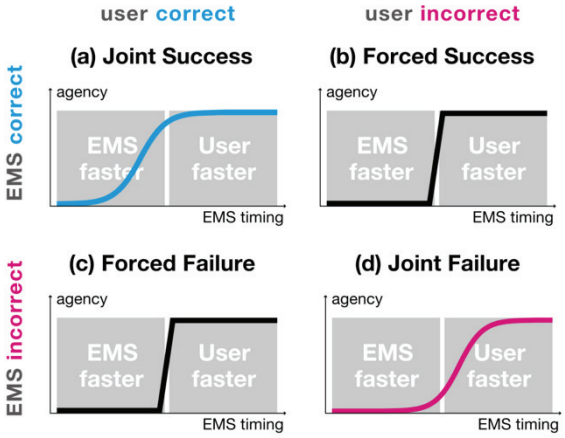

Fig. 4 Synthesized framework that enables researchers of digital-touch systems

2.4 ElectroMagnetic Actuation System (EMAS)

As the technical development for research on Self in Human computer integration, we engineered new finger actuation system called EMAS [3]. The ElectroMagnetic Actuation System (EMAS) is composed of mainly two parts; the finger attachment with the neodymium magnet and the electromagnet with micro-controllers. The finger attachment can be attached to multiple fingers of users, such as the index finger and middle finger in both hands. 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 or even preventing the press by repulsion. The attraction/repulsion power is approx. 2.0 N, which is enough to move the user's finger.

Fig. 5 ElectroMagnetic Actuation System (EMAS)

By integrating computer games and our EMAS system, we can induce player's volition for executing game actions, and EMAS can intervene in players' actions for the gameplay by real-time finger actuation. For instance, in the rhythm game, EMAS can actuate player's fingers by attracting fingers aligned with players volition, or EMAS can also interfere player's fingers by repulsion force, which is not aligned with players volition. And moreover, even without player's volition, EMAS can actuate fingers to execute the game perfectly but completely passive. Together all, EMAS system allows us to explore associate / dissociate motor actions from volition and sense of agency through the dynamic control of finger actuation.

In addition, by multiple EMAS together, we can enable a low-latency motion transfer system. EMAS enables small actuation latency (ave. 13.7 +/- 2.1 ms); the duration from electromagnet activation to finger-driven button pressing. This allows rapid motion transfer inter-personally by triggering finger actuation from other user's key input with inter-connecting multiple EMAS. Moreover, 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. Those multiple EMAS allow the motion transfer between players in milliseconds resolution, which will work as the significant technological set up to investigate the sense of agency and flow state among multiple persons.

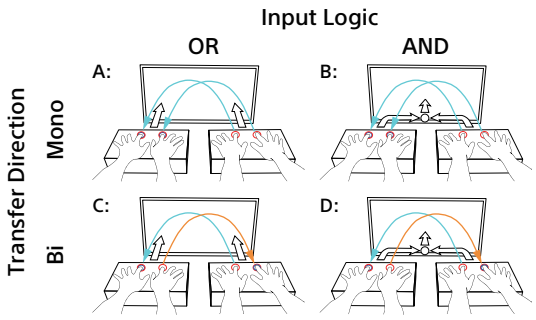

Fig. 6 type of motion transfer with EMAS

3. Beyond one mind one body

Cybernetic avatars technology will make a significant paradigm shift in the relationship between mind and body. Mind and Body will be no longer just one-to-one, but will be possible for one person to embody multiple bodies, or multiple people to embody one body together. We are researching the parallelization of three elements (Aware - parallelization of perception and cognition, Action - parallel behavior of multiple bodies, Attribute - self-attribution of parallel experiences) as key factors for going beyond one mind one body for parallel and integrated embodiment with preserving "self" in the new relationship between mind and body as “N minds M bodies“.

3.1 Parallel Ping-Pong

As the demonstration of parallel embodiment, we demonstrated Parallel Ping-Ping [4], a system that realizes “Parallel Embodiment”, the experience of a single user controlling multiple bodies simultaneously. The user plays ping-pong by controlling 2 robot arms using a Virtual Reality (VR) controller, while looking at 2 tables through a Head Mounted Display (HMD). The computer constantly calculates the ball trajectory and the motion for the robot arm to hit the balls back automatically through color cameras. Based on this calculation, the system integrates the motion of the user’s controller, maintaining the sense of agency of the robot arms even though single user plays ping-pong with two opponents. In addition, the user’s view through the HMD is automatically switched to the appropriate table according to the calculated position and direction, so that the user can perceive both tables’ situation smoothly. We exhibited a three-day Parallel Ping-Pong demonstration and surveyed 142 participants about their perception while controlling multiple bodies.

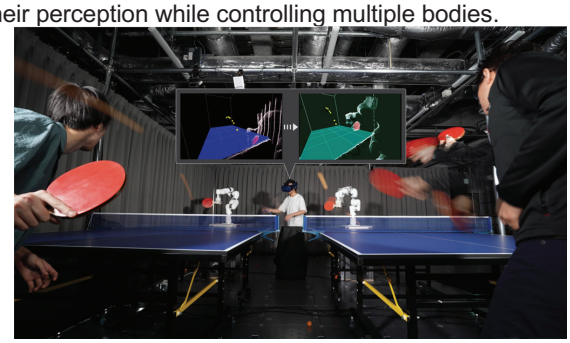

Fig. 7 Parallel Ping-Ping experience

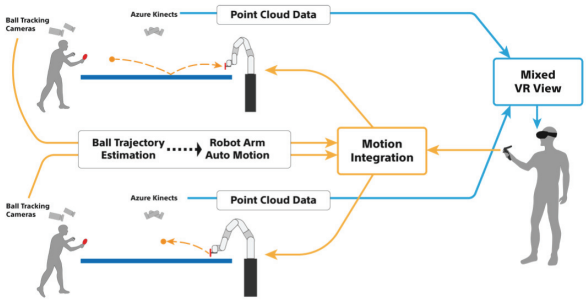

Fig. 8 Parallel Ping-Ping system overview.

3.2 Parallel Adaptation

Virtual Reality (VR) lets us experiment embodiment. Here we investigate dual embodiment under the prism of dual motor adaptation. We asked participants (N=21) to perform reaching motions in VR with opposite gradual visuomotor perturbations. The participants sequentially switched between 2 VR bodies and had to adapt to the VR body’s perturbation (up to +15° for the VR bodyA, and -15° for the VR bodyB). We then designed a 2x2 within-subject study: 1 factor being the perspective (1st person or 3rd person), and 1 factor being the head rotation (without head rotation before the reaching motion or with head rotation before the reaching motion). We found that by providing strong visual cues between bodies (alternating symmetric perspective and/or symmetric head rotation), participants had little awareness of the perturbations, good adaptation, and large aftereffects in both VR bodies. Those elements are consistent with implicit dual adaptation. In contrast, a naive 1st person perspective resulted in little to no adaptation with a high cognitive load and no aftereffects [5].

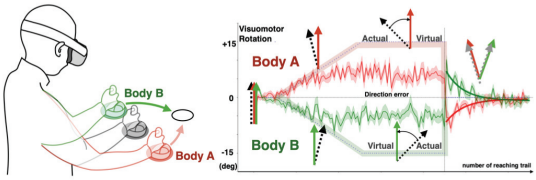

Fig. 9 Dual motor adaptation over two bodies

4. Contours of the sense of self

As a project on the contours of the sense of self in computer-mediated cross reality, I presented research on the ambiguity of human change perception and self-face attribution. Not only video chat but also image-mediated communication including metaverse is rapidly becoming common, and opportunities to recognize self and others from images are increasing. Since such self and other face recognition can be represented as a continuum on the information space, the boundary of self should exist somewhere. Here, I introduce a study on the self-face boundary value analyzed from the experience data of an exhibition that enables the experience of such a boundary between the self and others, and a discussion on the plasticity of the self-face boundary value and its application.

4.1 Human Latent Metrics

To describe the huma perceptual and cognitive metrics to measure the boundary of self. We investigated the correspondence between Generative adversarial networks (GANs) latent space and human perceptual and cognitive response [6].

Our studies investigated the relationship between latent vectors and human perception or cognition through psycho-visual experiments that manipulates the latent vectors of face images. In the perception study, a

change perception task was used to examine whether participants could perceive visual changes in face images before and after moving an arbitrary distance in the latent space. In the cognition study, a face recognition task was utilized to examine whether participants could recognize a face as the same, even after moving an arbitrary distance in the latent space.

Our experiments show that the distance between face images in the latent space correlates with human perception and cognition for visual changes in face imagery, which can be modeled with a logistic function. By utilizing our methodology, it will be possible to interchangeably convert between the distance in the latent space and the metric of human perception and cognition, potentially leading to image processing that better reflects human perception and cognition.

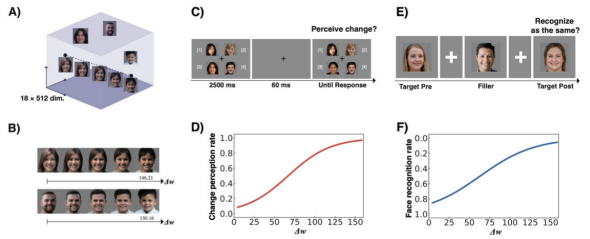

Fig. 10 Human Latent Metrics

4.2 Morphing Identity

We explored continuous changes in self-other identity through designing an interpersonal facial morphing experience where two persons' facial images are blended and then swapped over time. Both users' facial images are displayed side by side, with each user controlling their own morphing facial images, allowing us to create and investigate a multifaceted interpersonal experience. To explore this with diverse social relationships, we conducted qualitative and quantitative investigations through public exhibitions. We found that there is a window of self-identification as well as a variety of interpersonal experiences in the facial morphing process. From these insights, we synthesized a Self-Other Continuum represented by a sense of agency and facial identity. This continuum provides implications on social and subjective aspects in interpersonal communication that enables further scenario design, which would complement findings from research on interactive devices for remote communication.

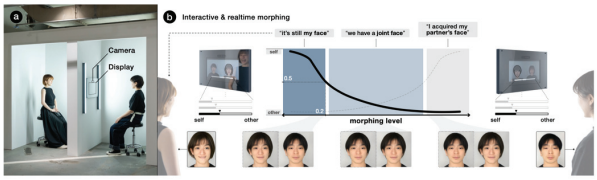

Fig. 11 Morphing Identity

5. Circulating Research and Experience

In our research group, we emphasize the experiencing of research toward social implementation phase. With circulating research and development and experiences, we aim to create a research cycle where everyone can participate throughout our artwork exhibitions and workshops as a dialogue with society. Our group is conducting research activities in collaboration with diverse collaborators including researchers, creators, and artists.

In the near future, a new relationship between mind and body in humans-computers integration will lead to major changes in our society, such as how we perceive "self", how we communicate with each other, and how technology will provide us with new abilities. By exploring these incoming challenges using current edge technologies, our research group aims to realize a better society where people and computers creatively integrate, harmonious integration into society.

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