Wearable Environments: Reconfiguring Human-Machine-Environment Relations

A. Baki Kocaballi

Design Lab
The University of Sydney

Wilkinson Building (G04)
148 City Road
baki.kocaballi@sydney.edu.au

ABSTRACT

Motivation – The main motivation is to gain a better understanding of agency between human, machine and environment relations mediated by a synthesis of wearable computing and smart environments technologies.

Research approach – The study follows a research through design approach. There are two main stages of the study involving a series of workshops involving designed prototype systems with different configurations. The prototype systems are designed based on the idea of "Wearable Environments" combining wearable computing and smart environments approaches to ubiquitous computing together. The interactions between prototype systems and human participants are analysed from a post-phenomenological perspective.

Findings/Design – The preliminary workshop study showed that the perception and interpretation of sonic and tactile feedbacks and consequently the strategies of subjects were highly dependent on the places of wearable devices attached to.

Research limitations/Implications – The study deals with only low-level cognitive actions and micro-perception shaping the machine-mediated human agency.

Originality/Value – The research will clarify some critical dimensions and aspects of complex phenomenon of agency in service of designing wearable environments by synthesizing the approaches of fields of wearable computing and smart environments.

Take away message – Wearable environments with enactive interfaces can provide unique opportunities for investigating and reconfiguring various forms of human-machine-environment relations.

Keywords

Human agency, wearable computing, smart environments, sensory supplementation, distal perception, sonic feedback, tactile feedback, enactive interfaces.

INTRODUCTION

The concept of agency is defined in its simplest sense as the capacity or potential for action (Suchman, 2006). Yet, there has been an ongoing debate in definition, emergence and possession of agency in artificial intelligence, cognitive science, philosophy and many other fields. One particular point of controversy is related to the attribution of agency to entities. Unlike the traditional humanist view of agency as a property of individual entities, Barad suggests that agency is not an attribute of subjects or objects or systems, but is "the ongoing reconfigurations of the world, an enactment" (Barad, 2003). Agency emerges out of the dynamism between the entities. There are two main views on the agencies of human and non-human agents: *symmetrical* or *asymmetrical*. In the symmetrical view, there are no differences between the agencies of human and non-human agents (Latour, 2005). Rammert suggests that having a symmetrical concept of agency enables us to analyse "the qualitative changes of the interaction between people and technologies and the reconfigurations of the hybrid constellations from which action emerges" (Rammert, 2008).

This study is particularly interested in dynamic agency between humans, machines and environment emerging out of these various hybrid forms of relations. We will investigate this machine-mediated agency using ubiquitous computing systems where smart environments and wearable computing meet.

BACKGROUND

Ubiquitous computing aims to embed computers into our daily routines in such ways as to render them invisible. Smart environments (Cook and Das, 2004) and wearable computing (Mann, 2001) are two important approaches to developing ubiquitous computing technologies that are increasingly shaping the design of our interactions with other people and the environment. While smart environments embed sensors and computing capabilities into the environment, wearable computing technologies place them onto the body as wearable garments or portable accessories. Smart environments have to interact with not just one person but with all the people in a space: they provide more generic, less intrusive interfaces (Rhodes et al., 1999). In contrast, wearable computing interfaces have to interact with only one person, and can be more personalized and interact in more proximate and more intimate ways (Mann, 2001).

Smart environments and wearable computing have typically been combined only to overcome technical limitations like reducing the computational complexity, increasing the effectiveness, or resolving privacy issues (Rhodes et al, 1999). Our research takes a different approach by integrating wearable computing and smart environments with a focus on exploring the opportunities for new types of human experience and to investigate new forms of agency.

Sensory supplementation devices can provide us unique opportunities to investigate the different aspects of our agency by means of enabling new modes of perception and facilitating the emergence of novel interactions, which are not possible without them. Sensory substitution systems transform stimuli characteristic of one sensory modality into stimuli of another sensory modality (Lenay et al 2003). TVSS (Tactile Vision Sensory Substitution) was one of the very early sensory substitution systems for helping visually impaired people. TVSS was a vision-to-tactile system converting the image of environment captured by a video camera into tactile stimulation produced by a matrix of 400 activators (Bach-y-Rita et al 1969). Participants experimenting this system were able to interpret this tactile stimulation to bat a ball as it rolled off a table.

Despite the fact that the sensory substitution systems were originally designed for handicapped people, they also facilitated exciting research on perceptual and cognitive studies and philosophy. The features that make sensory substitution systems a suitable tool to perform practice-based research in these areas include the provision of a novel perceptual modality and the role of action in perception: creating a "new space of coupling between human being and the world" (Lenay et al 2003). In this study, we investigate different aspects of our agency by means of new modes of perception and novel interactions enabled by a sensory substitution device.

THE AIMS AND OBJECTIVES OF THE RESEARCH

The main motivation behind this research is to gain a better understanding of relations between humans, machines and environment mediated by ubiquitous computing technologies. The research focuses on the impact of these technologies on two main dimensions of our agency: perception and action. Consequently, the aim of the research is to find how these technologies designed according to the idea of wearable environments shape the ways we perceive the world, and the ways we act in this world.

One of the main objectives of the research is to develop a framework of machine-mediated agency for designing interactive multi-agent systems distributed over bodies and space. Wearable environment system will be a special case of this kind of systems to be designed and evaluated according to this framework. Another objective is to investigate the changes in "perceived agency" of technological agents with respect to their level of intelligence and their physical configuration.

THE CONTRIBUTION OF THE RESEARCH

This research situates emerging human-machine relations into a distributed machine-mediated agency framework, which provides a workable account of agency in service of designing wearable computing and smart environment systems. This framework will provide tools for designing and assessing machine-mediated agency according to physical configurations of agents in space and their level of intelligence. Moreover, the study will produce a series of prototype systems, which can enable new forms of relations and interactions between human, machine and environment.

METHODOLOGY

This research follows a design-oriented research approach (Fallman, 2003) and relies on the continuous cycle between practice and theory feeding each other. Actor-Network Theory by Latour (2005) and the post-phenomenological perspectives suggested by Ihde (1990) and Verbeek (2005) will guide the development and evaluation of our framework. We employ a low-fi rapid prototyping approach to develop our systems. The research is comprised of two main stages. In the first stage, we will explore the relation between agency and different kinds of embodiment relations of humans, machines and environment through the experimentation of different physical configurations of technological agents in space. In the second stage, we will investigate the relation between agency and pure reasoning capacity of technological agents through the experimentation of different levels of machine intelligence.

PRELIMINARY EXPERIMENT

The works of Lenay and Steiner (2007) and Grespan et al (2008) using a minimalist interface to understand the different characteristics of perception inspired the design of our preliminary experiment. We have built a small mobile sensory substitution device called the Enactive Coupler (EC), Figure 1. It is equipped with one ultrasonic range finder sensor and two vibration motors and similar to the Enactive Torch (Grespan et al 2008) in terms of distance-to-tactile functionality. However, unlike the Enactive Torch, EC can be attachable to different parts of the body or placed onto different surfaces in the environment. This flexibility enables us to experiment the different configurations between the bodies and space. EC also features sonic

Figure 1. The Enactive Coupler (EC)

output, which is produced mechanically by the amplified sound of an additional vibration motor.

We conducted two preliminary workshop sessions with 4 participants. These were intensive sessions comprised of 4 activities lasting about 3 hours in total. Participants have performed each activity in pairs but there was only one pair at a time. We thought that by having participants in pairs, we could examine interpersonal enactive interactions towards understanding body-to-body couplings. Participant 1 was an architect aged 24, Participant 2 was a visual artist aged 26, Participant 3 was a psychologist aged 25 and Participant 4 was a musician aged 23.

Activities

All the activities were designed like a game with the same objective of guiding a blindfolded partner over randomly established tracks with different tools or configurations. For each activity, there were a guiding participant (GP) and a blindfolded participant (BP). For making the task simpler, the angle of turning points on track was always 90°. There were four main activities, illustrated in Figure 2, in which the same pair of participants performed each activity twice by switching the roles of BP and GP.

Activity 1: *GP guiding BP with a rope extending from back of GP to stomach of BP.*

Activity 2: *GP guides BP with EC attached to stomach of BP.*

Activity 3: *GP guides BP with EC attached to back of GP.*

Activity 4: *GP guides BP with EC attached to hand of BP.*

Participants were not allowed to talk to each other. They were only able to communicate through the tools provided and by non-verbal ways without touching each other. There were two tools utilizing individual's perception of distance: a simple rope about 60cm long and EC. We considered the rope as an enabling constraint for making analogies to figure out ways to coordinate movements between bodies when participants were asked to use EC.

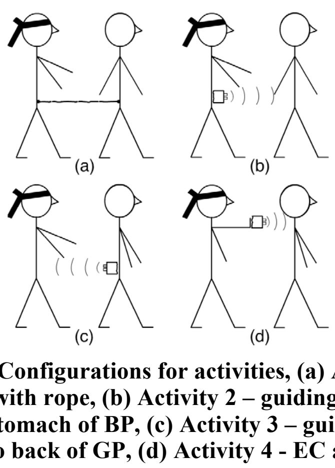

Figure 2. Configurations for activities, (a) Activity 1- guiding with rope, (b) Activity 2 – guiding with EC attached to stomach of BP, (c) Activity 3 – guiding with EC attached to back of GP, (d) Activity 4 - EC attached to hand of BP

After the completion of each activity, we delivered response cards and interviewed with the participants. We have made use of the answers on response cards, follow-up interviews and video recordings to analyse the activities.

Findings

We analysed the results from the four activities according to three perspectives: perceptive coordination strategies, interpretation of sonic and tactile feedbacks, and awareness of the partner and the space.

Perceptive Coordination Strategies

The participants' strategies to carry out the tasks revealed important aspects of negotiation and evolution of mutual intentions and influences, which are important dimensions of our agency.

The participants pointed out that Activity 2 was the most complicated one for them as they needed to both control the device and search for their partners. Participants considered activity 4 as a hybrid of Activity 2 and Activity 3 and hence they employed a hybrid strategy of previous two activities based on the principles of *following a signal* and *confirming the rightness of their body movement and orientation*.

The first activity with the rope clearly influenced the negotiation of coordination strategies developed in later activities. In a few cases, GPs were able to find alternative ways of coordination with their partners, even though they were still acting in accordance with the rope model of coordination. They faced with their partner and caught the signals of EC with their hands. In the last activity, one GP went beyond the rope model by directing the BP while he was not moving over the track. This was a significant deviation from all other strategies, which are based on the idea of having both partners moving together over the track. Here, GP was performing at another level of agency. GP was using the same interface for communicating with BP, but was able to act in a different way. GP knew what BP was expecting based on their previous model of interaction and provided appropriate inputs while acting according to another new model of "coupling" evolved from the base rope model of coupling.

Interpretation of Sonic and Tactile Feedbacks

The role of sonic and tactile feedback changed within and across the activities. These changes bring out two important aspects: the importance of different placements of sensory substitution devices in meaning generation and fluent transition of participants from one feedback model to another one. Participants were able to adapt to these changes at three levels: (1) they adapted their perception of distance with respect to changing places and influences of sonic and tactile stimulus; (2) they adapted their own movements to this new coupling by negotiating this new space of possibilities for action with their partner; and, (3) the meanings of the feedbacks were determined and reappropriated mutually during this negotiation process.

Awareness of the Partner and the Space

BPs all agreed on that they felt the presence of their guiding partner at most in Activity 1, then in Activity 3, then in Activity 4 and the least one in Activity 2. There was not a common pattern for awareness of the space, but BPs all said that it was at the lowest level in Activity 2. The awareness of the presence of the GP was directly affected by the placement of EC. When the EC physically got closer to the GP's body, BP's awareness of GP increased. In general, the EC provided a proximity-based representation of entities to BPs. However, the association of this representation to individual entities depended on the physical distance between the entity and EC. The association of a representation with the entity was at a maximum when EC is physically attached to that entity and at a minimum when EC is carried by BPs. From this point of view, distributing ECs to the environment could increase the participants' awareness of space and of the other entities in that space.

DISCUSSION AND FUTURE WORK

This experiment showed that the perception and interpretation of sonic and tactile feedbacks and consequently the strategies of subjects were highly dependent on the places sensory substitution devices attached to. This may have significant implications for the design and evaluation of similar sensory substitution devices and perhaps more generally on wearable devices with enactive interfaces.

Participants developed different strategies in each activity to coordinate their movements based on different couplings. The couplings were not predetermined but emerged from the process of negotiation between participants, supported by the EC. However, these coupling were not completely unexpected. The grounding experience of the rope activity, as well as the different placements of the EC, served as enabling constraints. While these constraints allowed movement to remain predictably connected to a desired model of coupling, they also enabled new possibilities.

We will continue to investigate different physical configurations in space and resulting couplings by a series of case studies involving EC-like devices. In the second stage, we are planning to investigate the role of higher degrees of machine intelligence in perceived agency of technological agents. The outcomes of these two stages will constitute the two main dimensions of the wearable environment model and inform the design of our framework of machine-mediated agency for designing interactive multi-agent systems distributed over bodies and space.

ACKNOWLEDGMENTS

The author would like to thank Petra Gemeinboeck, Rob Saunders and Markus Rittenbruch and the study participants. This research is co-funded by University of Sydney and NICTA, Australia's ICT Research Centre of Excellence.

REFERENCES

Bach-y-Rita, P., Collins, C.C., Sauders, F., White, B., Scadden, L. (1969). Vision substitution by tactile image projection. *Nature 221,* 963–964.

Barad, K., (2003). Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter. Signs: *Jr. of Women in Culture and Society,* 28(3).

Cook, D., and Das, S. (2004). *Smart Environments: Technology, Protocols and Applications.* Wiley

Fallman, D. (2003) Design-oriented human-computer interaction, Proc. of Human factors in computing systems, ,Florida, USA

Grespan, L., Froese, T., Di Paolo, E. A., Seth, A., Spiers, A. & Bigge, W. (2008), "*Investigating the role of movement in the constitution of spatial perception using the Enactive Torch*", Proc. of the Conf. on Enactive Interfaces, Pisa, pp. 105-110

Ihde, D. (1990). *Technology and the Lifeworld*. Bloomington: Indiana University Press.

Latour, B. (2005) *Reassembling the Social: an Introduction to Actor-Network Theory*. Oxford University Press

Lenay C, Gapenne O, Hanneton S, Marque C, Geouelle C . (2003). Sensory Substitution: limits and perspectives, *Touching for Knowing, Cognitive psychology of haptic manual perception*, 275-292

Lenay, C. and Steiner, P. (2007). *Externalism and enaction*. *Proc. of the 4th Int. Conf. on Enactive Interfaces* Grenoble

Mann, S. (2001). Guest Editor's Introduction: Wearable Computing-Toward Humanistic Intelligence. *IEEE Intelligent Systems*, 16(3), 10-15.

Rammert, W. Distributed agency between humans, machines and programs In Uwe Seifert, Jin Hyun Kim and A. Moore (Eds.), Paradoxes of Interactivity: Perspectives for Media Theory, Human-Computer Interaction, and Artistic Investigations. Transcript Verlag (2008), 62-91

Rhodes, B. J., Minar, N., and Weaver, J. (1999)Wearable Computing Meets Ubiquitous Computing: Reaping the Best of Both Worlds. Proc. ISWC09, IEEE

Suchman, L.A., (2006). *Human-Machine Reconfigurations: Plans and situated Action*. Cambridge University Press

Verbeek, P-P, (2005). *What Things Do – Philosophical Reflections on Technology, Agency, and Design*. The Pennsylvania State Press