Physical Computing – Representations of Human Movement in Human-Computer Interaction

Astrid Twenebowa Larssen

Faculty of Information Technology, University of Technology, Sydney,
PO Box 123, Broadway NSW 2007, AUSTRALIA, atalarss@it.uts.edu.au

Abstract. Interactions between humans and computers are becoming increasingly physical. Technology is embedded in the environment around us and is now hosted by the human body. This research explores characteristics of human-computer interaction when the human body and its movements become input for interaction and interface control.

1 Context of research

Interaction between humans and computers depends on humans communicating intentions to the computer, using input devices, in such a way that the computer can interpret them. This is coupled with the use of output devices to provide relevant information from the computer in a form that is perceivable by humans. The interaction is structured by various protocols [12]. This research investigates the characteristics of human-computer interaction when the human body and its movements are themselves the input for interaction.

The input-output interaction loop between humans and technology is a sequence, all stages of which need to be at least partially successful to enable the interaction. These stages are:

1. People communicate their intentions to technology;
2. The computer receives, interprets, and acts on this information (the intentions);
3. The computer represents its relevant workings and results to an output device; and
4. People perceive these representations, and act accordingly.

The use of the human body and its movements for input for interaction and interface control presents challenges to all stages. For example:

1. Research to extend input options has focused on extending the capabilities of the current devices by developing new devices and related techniques for the manipulation of objects [4, 11], including multimodal input [10], and the use of physiological data [1].
2. *Computer vision, motion capture and recognition*, and *image processing* are all fields that explore approaches and techniques for the computer to receive and interpret human intentions.
3. Currently, feedback on movement is mainly limited to changing visual cues [5, 6], or tactile feedback, which incorporates the sense of touch in the interaction [14]. Auditory feedback is mainly used as an extension of visual feedback, and is less frequently used on its own.

4. Different understandings of human action, including cognition have demonstrated that human perception is structured both by human physical and cognitive abilities [13, 15, 16, 17, 18].

The input-output interaction loop describes the actions of humans and the actions of the computer. The interaction between the two is only captured in the synthesis of the two working together.

For an understanding of the place of the body in the world and subsequently to technology, we look to Merleau-Ponty's phenomenology [8]. His account of the *"lived experience of the embodied subject, as the basis of both our experiences in our world and our agency in our actions within it…"* [13], can inform technology design through its analysis of the body's role in perception. According to Merleau-Ponty, perception is active, embodied, and always generative of meaning.

Mine et al. proposed a design framework based on *proprioception* [9]. They describe three forms of "body-relative" interaction techniques:

- Direct manipulation - ways to use body sense to help control manipulation;
- Physical mnemonics - ways to store/recall information relative to the body; and
- Gestural actions - ways to use body-relative actions to issue commands.

In the implementation of this framework Mine et al. developed and tested interaction techniques such as "head butt zoom" and "over-the-shoulder deletion". Ängeslevä et al. proposed a similar interface design concept, "Body Mnemonics", which explores embodied interfaces by using a combination of the physical space and the body of the user as an interface [2].

Mine's and Ängeslevä's design frameworks for immersive virtual environments and portable devices, respectively, are relevant for this research as they consider the body a key part of the interaction, "*...most existing theories in human-computer interaction (HCI) treat the body as a machine executing commands of a disembodied logical mind."* [16]. However, the body creeps up on HCI in several ways:

- The make up (shape, size etc.) of the physical body determines what kinds of physical interactions are possible [16];
- The physical skills of a person determine what interactions actually will take place [16];
- The body gives meaning to the interactions. The premise of experiencing a virtual reality rests on our having had the experience of a physical body [17]; and
- The structure of the body and bodily experiences form the background and colour the meaning given to the experiences [16].

2 Research Design

Using these theoretical foundations, the focus of my research is to investigate characteristics of human-computer interaction when movements of the human body become the input device for interaction and interface control. The outcomes sought are to develop:

- an understanding of the techniques currently used;
- an evaluation of the effectiveness of these techniques;
- new interface and interaction design principles which can extend existing user-centred design guidelines; and

- new evaluation methods that can extend existing user-centred design methods.

It is envisaged that a *kinaesthetic* understanding of the movements of the human body will lead to more appropriate frameworks for interaction design. The extension of *input options* to include the human body as host technology [18], and for the human body and its movements to become input for interaction and interface control, needs an *understanding of how best to represent and characterise the human movements that the computer has to register*. Further developments of *output devices* rely on our understanding of how people *perceive* representations of their movements.

The research will be undertaken in three distinct parts; each step will be used to refine the research questions, and to determine the appropriate setting for further studies. The first phase aims to identify the techniques used by current systems to represent and characterise movement of the human body. It is an observational study of computer games that use the human body and its movements as input. Computer games were chosen for the study, as they are easily accessible, existing systems. The second phase is an in-depth study to evaluate the findings and issues from phase one for generalisability and extendability to human/computer interactions other than games. This could involve the development of a prototype and evaluation of this prototype in a laboratory or in a real use situation and/or further investigation of findings from the first phase. The third phase is dependent on the two preceding phases; more concrete statements will be made about this phase by the time of the doctoral consortium. However, it is envisaged that this study will test the design principles that have been developed, by either a build and/or evaluation of phase two.

3 Progress to Date

The first study was carried out to gain an understanding of the techniques used by current technology to represent movement of the human body, as well as to explore ways of documenting and analysing the bodily actions taking place. Video, demographics and interview data were gathered from eight people playing immersive computer games. The methods used were adapted from participant observation and game usability evaluation.

Four female and four male participants were recruited from staff and students at the University of Technology, Sydney. The participants were invited to play two games using the SONY Playstation2® with the Eyetoy™. The two games, *Beat Freak* and *Kung Foo*, were selected by the researchers, because they required a range of user movements while being fairly easy to learn.

Beat Freak requires the player to move their hands over a speaker in one of the four corners of the screen at the same time as a CD flies across the speaker. The CDs fly out from the centre of the screen and reach the centre of the speaker in time with the music. In Kung Foo the player needs to intersect with little Wonton henchmen to prevent them from reaching the middle of the screen. The Wonton henchmen appear randomly from both vertical edges of the screen. Extra points are gained by breaking wooden boards, and slapping Wonton himself.

After a warm-up session of light moves and stretches, the participants were introduced to the game via its *Help* feature. Each then played both games twice on the “easy” level and once on the “medium” level. The participants were filmed from two angles. One view captured the participants’ projection on the screen; the other view captured the participants’ full body whilst playing. Data on demographics and previous experience with the games was collected prior to playing. The participants were interviewed about their experience with the game, and asked usability related questions in a post briefing sessions.

Interaction with the Eyetoy™ games, Beat Freak and Kung Foo, produced a range of movements, primarily movements of the torso and arms. An examination of both games including menu selection identified the following movements: reach, punch, slap/swat, wave, slash, and flick.

The movements were performed either as a:

- *Command* in the selection of game choices and settings;
- *Reflex response* by hitting either a:
  - stationary object;
  - moving object by coinciding with target location; or
  - moving object as soon as the object appears.

These movements were analysed using *Labanotation*, a notation used to describe bodily action developed by dance/movement theoretician Rudolf Laban [7]. When transcribed, it became evident that each game has its own set of basic movements that will enable game play. Laban’s *Effort-Shape* dimensions of *space, time, weight* and *flow*, described in terms of *light – firm* (space); *direct – flexible* (time); *slow – fast* (weight); *bound – free* (flow), revealed that each participant played with individual styles and characteristics. The Effort-Shape dimensions provided detailed qualitative description of these individual/distinctive movements. It remains to be discovered whether any of these styles are more effective for game play. The Eyetoy™ interface is tolerant of movements with different characteristics, provided that the movement takes place within range of the sensor.

Further analysis will include developing a taxonomy of movements and actions for the Eyetoy™ interface, an analysis according to the *sensible, sensable, desirable framework* [3], and investigation of how the body reciprocates the different game events, such as navigating, choosing, waiting, and playing. The results of these analyses will be presented at the Doctoral Consortium.

The next phase of this research will evaluate the findings from the first study for generalisability and extendability to human/computer interactions other than games.

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