

Frames of Reference for Portable Device Interaction

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ABSTRACT

Increasingly, our mobile devices are acquiring the ability to be aware of their surroundings, both their physical environments and their digital neighbourhoods. Alongside this awareness of the outside world, these devices are acquiring the ability to sense what is happening to them - how they are being held and moved. The coincidence of connectedness, awareness and richly multimodal input and output capabilities brings into the hand a device capable of supporting an entirely new class of haptic or touch-based interactions, where gestures can be captured and reactions to these gestures conveyed as haptic feedback directly into the hand. Thus one can literally shake the hand of a friend, toss a file off ones PDA, or be lead by the hand to a desired location in a strange city. While this new interaction paradigm opens up a vast array of potential application domains, it also poses a number of challenges. In particular, how can such devices support interactions that will have consequences in environments with different spatial frames of reference – the world-centred frame of reference of the location-aware application, the body-centred frame of reference of the gestural interface, and the device-centred frame of reference of a screen-based application. This paper presents some prototype applications for handheld devices that explore the implications of different frames of reference for actions in the mobile context.

Author Keywords

Portable devices, Haptic Interfaces, Gestural Control, Frames of Reference.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI)

INTRODUCTION

Portable devices are becoming more and more powerful and the types of applications they can support are becoming more sophisticated. Increased processing power, memory and the addition of multiple forms of motion and location sensing bring into the hand a device capable not only of supporting more demanding applications such as video capture and editing, but also of supporting entirely new forms of interaction. However, the development of many applications for the portable context has often been seen as an adjunct, or at most a parallel to that of their desktop relatives. This approach has resulted in a one-size-fits-all solution for the design of interaction with such applications in situations where screen real-estate is limited and the range of motion supported by pointing devices such as joysticks on phones is at an entirely different scale to that being engaged in by the user in the mobile context. Crossan et al [2], for example, have shown that people are less accurate at selecting targets on a PDA when walking versus sitting but that, when walking, people are more likely to tap items in synchrony with the downward phase of the walking gait, suggesting that the motion of walking does effect their interaction with the portable device.

Alongside the scale of a gesture or action, a second factor to be considered, and the factor which is the primary focus of this paper, is the frame of reference of the interaction. In other words, where is the interaction embodied? Is it entirely contained within the hand-held device (e.g. an address list) or is it embodied in the world (a location-aware application such as a map). Moreover, how do both of these spaces relate to the user's own body space, the fundamental frame of reference for their own motion and action?

THE ROLE OF THE BODY IN EMBODIED INTERACTION

The term 'embodiment', defined by Dourish as 'the transition from the realm of ideas to the realm of everyday experience' [9], encompasses not only physical embodiment (of objects such as tables and chairs), but also embodied actions such as speech and gesture. For Dourish, the notion of embodiment is related to Heidegger's phenomenological approach to the world and the way we act upon it. Heidegger distinguished between two

categories of interaction -those where the world is present ("vorhanden") and where the world is acted upon ("zuhanden"). Dourish translates these concepts as "present-at-hand" and "ready-to-hand", and suggests that embodiment is equivalent to Heidegger's concept of "zuhanden". Dourish argues that a Human-computer interface is, when acted upon, "ready-to-hand".

The concept of body-mediated or embodied interaction, of the coupling of interface and actor, has become increasingly relevant within the domain of HCI in general and presents particular opportunities for the domain of mobile device interaction in particular. With the reduced size and cost of a wide variety of sensor technologies and the ease with which they can be wirelessly deployed, on the body, in devices we carry with us and in the environment, comes the opportunity to use a wide range of human motion as an integral part of the interaction with all sorts of applications. As Fishkin et al have pointed out [5], There are many directions in which HCI design is developing beyond the GUI, all of which move toward a greater integration of the body's motion and its sense of its own motion in interaction design. Virtual Reality (VR) approaches a situation where the user is drawn into a high-quality, animated 3D world on the display. In its extreme, the display migrates onto the user's body as goggles, headphones and even touch-feedback-enabled clothing. The second approach that of Augmented Reality (AR) [9], recognises that computation is embodied in physical devices that exist as elements in the physical world and that the physical configuration of these computational devices is a major determinant of their usability. A third approach, that of Enactive Interface design [4], places the body at the centre of the interaction.

How does the notion of embodiment relate to enaction? Varela, Thompson and Rosch define the relationship thus:

“By the term embodied we mean to highlight two points: first, that cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context. By using the term action we mean to emphasize once again that sensory and motor processes, perception and action, are fundamentally inseparable in live cognition.” [8]

The enactive approach, then, consists of two elements: (1) perception consists in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided. Thus, enaction can be considered to be a specific case of embodiment, where the 'body' that provides structure and meaning for the interaction is that of the user. This subtle shift of the seat of embodiment from the world to the body provides the opportunity to reconsider the role of motion and action as elements of interaction, because it allows for notions of embodied knowledge to inform

design. Enaction does not preclude either VR or AR approaches, but merely introduces the notion of the body as the meaning-making mechanism in the increasingly physically encompassing world of the human-computer interface.

ENACTION AND TOUCH

The consequence of adopting an enactive approach to the design of interactions with portable devices is a shift of emphasis that acknowledges that the body is far more capable of discovering meaning in the context of the physical world than any artificially constructed metaphor. Here the sense of touch is key - without a sense of touch we cannot move and without moving we cannot act. As Mine et al point out [6], without touch, a user can no longer feel their surroundings to tell where they are or use the felt collision with stationary objects to refine spatial perception. Further, they cannot Use the inertial properties of wielded objects to refine tool manipulation. In short the combined feedback from tactile and haptic proprioceptive systems provides a myriad of cues that help us move and act in the world: The tactile sense, mediated by receptors in the skin, relies on movement between the skin and an object's surface in order for any sensation to be perceived - without movement, objects disappear from our tactile view.

The kinaesthetic sense, mediated by receptors in muscles and joints, must support the tactile sense by providing information about motion and self-motion. The proprioceptive sense, in turn, orients the entire system with respect to gravity and the outside world.

If we are to take on board the implications of the enactive approach to interaction design within the context of mobile device interaction, then we cannot overlook the importance of touch in the acquisition of the kind of embodied knowledge we rely on for physical interactions with the environment. However, the complexity and interdependence of the touch senses requires an approach to the design of applications that use touch where its various roles in sensing, motion and action are well understood and supported by appropriate sensory cues.

FRAMING ACTION – SOME DESIGN EXAMPLES

Over the past three years, the Palpable Machines group at Media Lab Europe developed a handheld platform for prototyping applications to test the hypothesis that tightly coupling motion (of the user) with touch feedback (from the handheld device) could unlock some of the potential for acquiring and using enactive knowledge in the context of portable device interaction. That is not to say one can't acquire tacit knowledge of the interface to an existing PDA or phone. What concerned us was the appropriateness of the scale of motion and the coherence of frames of reference for actions to be performed.



Figure 1. Body Mnemonics



Figure 2. Topographic Torch

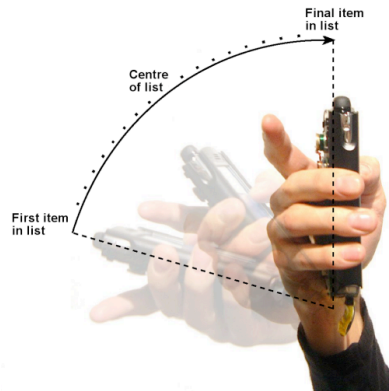


Figure 3. Tilting Lists

Broadly speaking, our prototypes fall into three categories that are distinguished by the frames of reference for their interaction. The first category is that of device-centred interactions, where the world of the application is contained within the device – i.e. the device embodies the set of tasks it supports. Here we were interested to discover whether adding haptic feedback would really result in improved performance in a tilt-to-scroll task because the action of tilting would have an associated haptic reaction from the device. We tested two scrolling paradigms, absolute versus relative scrolling with respect to tilt, and found that the presence of haptic feedback to indicate the movement of the cursor from one item in the list to the next significantly improved performance, particularly at the boundaries of the list where the angle of the screen with respect to the user was most extreme [7]. One important factor to note here is that while the world of the application was certainly contained within the device, it was the user’s knowledge of the position of their hand with respect to gravity, their proprioceptive knowledge, that provided meaning for the tilt-based interaction.

The second category of applications used the body itself as the frame of reference for interaction with the portable device. For ‘Body Mnemonics’, the user’s body becomes the reference frame for storing and retrieving information in their portable device [1]. While the application in its final form has not been empirically tested yet, results of a conceptual study where participants placed information in locations around an image of a body and were asked to recall where they had put their data a week later, indicate that the concept of placing and retrieving information in this way is potentially very powerful. What remains to be tested is whether in practice such an interface improves people’s ability to access their information while they are moving.

The third category of interest, that of applications where the physical world provides the frame of reference for actions, is perhaps the most interesting. Here we have developed an egocentric map based on the metaphor of a torch so that. As the person holding the device turns to view their surroundings, the map also rotates so that it is always overlaid precisely on the physical environment. They can then tilt the device to zoom their map view, much as if they were casting the beam of a torch onto the world around them. Here it is hoped that the automatic alignment of the

world and map views, combined with the egocentric perspective, will support the user in building a physically grounded understanding of the mapped space around them.

It is worth noting here that, though not strictly related, there are some interesting similarities between the three categories of applications we chose to develop and the paradigms for interaction with VEs described by Mine et al [6].

Their 'Direct Manipulation' paradigm, where they looked at ways to use haptic proprioception to control manipulation in VEs, loosely maps to our device-centred approach. Their second category of 'physical mnemonics' directly corresponds to our body-centred approach and their third paradigm, 'Gestural Actions' (i.e. ways of using body-centred actions to issue commands), encompasses all three approaches, but is particularly relevant for the Topographic Torch.

With respect to frames of reference for action, an important question which must still be addressed for all interaction paradigms is what happens if the frame of reference for an interaction is not constant, either in scale or locus. As we have already noted, the scale of motion appears to effect the way people interact with mobile devices while walking. Is there a similar cost associated with moving between different spatial frames of reference for their actions or does the body's sense of its own space act to mediate any apparent disparities.

SUMMARY

The increased availability of low-cost sensors and actuators provides us as designers with an unprecedented opportunity to reconsider the way in which we design interfaces for portable devices. However,

the use of motion as an input modality is likely to require that the locus of an action and any associated feedback, be situated in a clearly defined reference frame. As mobile devices become more powerful, the designer of applications for the mobile user is likely to have to negotiate a design space with multiple frames of reference for a user's actions. Here a better understanding of the senses of touch, of the body's motion and its sense of its own motion, may be the

key to providing a meaningful bridge between multiple, interleaved and interdependent spaces.

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REFERENCES

1. Ängeslevä, J., Oakley, I., Hughes, S. & O'Modhrain, S., Body Mnemonics: Portable device interaction design concept. In Proceedings of UIST'03 November 2-5 2003
2. Crossan, A., Murray-Smith, R., Brewster, S., Kelly, J., and Musizza, B. Gait Phase Effects in Mobile Interaction. In Proceedings of CHI '05, Portland 2005
3. Dourish, P. 'Where the Action Is', MIT Press, 2000.
4. Enactive Network <http://www.enactivenetwork.org>
5. Fishkin, K. P., Gujar, A., Harrison, R. L., Moran, T. P., and Want, R. Embodied User Interfaces for really Direct Manipulation. Communications of the ACM 43, 9, September 2000
6. Mine, M., Brooks, F., Séquin, C., "Moving Objects in Space: Exploiting Proprioception in Virtual-Environment Interaction," Proc. of SIGGRAPH '97, 1997.
7. Oakley, I. and O'Modhrain, S. Tilt to Scroll: Evaluating a Motion Based Vibrotactile Mobile Interface In IEEE Proceedings of the World Haptics Conference, March 2005.
8. Varela, F., Thompson, E., Rosch, E. (1991). The Embodied Mind. Cambridge, MA: MIT Press.
9. Weiser, M. The computer for the 21st century. Scientific American 265, 3 (Mar. 1991), 94-104.