Can Tangible User Interface Concepts be used for Describing Everyday Object Manipulation?

position paper for the CHI2007 workshop on Tangible User Interfaces in Context and Theory

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Overview

The main part of this position paper presents our emerging design framework "egocentric interaction" aimed to help structuring the design of support systems for personal everyday activities. The particularity of the proposed model is a) the choice to center the activity modelling around a specific human body rather than a computing device or other artefact, and b) the attempt to cover object manipulation performed by human individuals both in the real world and in the virtual world (i.e. taking place "inside" interactive computing devices). The idea of complementing the egocentric interaction framework with existing concepts from within the area of Tangible User Interfaces is raised, motivated by the need to model everyday object manipulation in more detail. The last section of the paper relates our design approach, focusing on the "what" rather than the "how", to more technology-driven design approaches.

Egocentric Interaction

The egocentric interaction framework differs from more classical HCI models by explicitly ignoring input and output devices of interactive computers such as PCs, PDAs and cellular phones, seeing them as completely transparent mediators for accessing virtual objects. Doing so permits the modelling of real-world and digital entities as if they were situated in the same Euclidean space. We believe that it is advantageous when modelling everyday mobile computing applications where the interaction complexity vastly surpasses what can be sufficiently described using a classical human-computer interaction dialogue model. By viewing the physical and the virtual worlds as equally important for human activity, the proposed physical-virtual perspective is a completely different way of modelling the relationship between the physical and virtual world compared to for instance how it is typically done in context awareness research where the physical world almost always is treated as mere context to the virtual world.

The term 'egocentric' has been chosen to signal that it is the body and mind of a specific human individual that (sometimes literally, as will be shown later) act as centre of reference to which all interaction modelling and activity support is anchored.

A Situative Model of Physical-Virtual Space

The egocentric interaction framework is based on a situative model of what a specific human agent can see and not see, reach and not reach at any given moment in time (Fig. 1). As a direct consequence of applying the physical-virtual design perspective outlined earlier, physical and virtual domain objects are treated as being located in the same space.

Example: In the situation when a glass of juice is in the left hand of a specific human actor, and an email just brought forward on the cellular phone held up in front of the same human agent's face by the right hand, both objects would be considered to

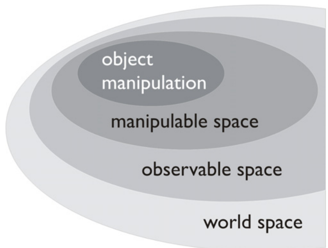

Fig. 1. A situative space model (adapted from [4]). Spaces can contain both physical and virtual objects.

belong to the human actor's object manipulation. A newspaper on the table just in front of the human actor, and the keys in that person's pocket would be modelled as inside the manipulable space. A painting on the opposite side of the table (but not the one behind the agent's back) would be in the agent's observable space. Finally, all technically perceivable objects in the physical-virtual world which at least for the moment not happen to be perceivable by the specific human actor are regarded as situated in the world space, outside the previously mentioned spaces.

It is At the Borders Where the Action is

In the physical world, the border between the observable and manipulable spaces can be approximated and described in Euclidean terms: manipulable things are typically closer than things only observable and the border is somewhere in-between. This spatial relationship is reflected in Fig. 1. Determining the same border in the virtual world is somewhat more complex and depends on situative access to input and output devices. Due to the nature of the application area towards which our current system development efforts is targeted (see next section of this paper), we have chosen to temporarily suspend the work on investigating how object manipulation and navigation in virtual environments (e.g. WIMP-kind) should be best modelled to fit into the situative space model shown in Fig. 1. We are however convinced that this is doable[1].

As a specific human agent changes location, objects come into and leave the observable space in a dynamic fashion. Based on a somewhat simplified model of human perceptional limitations, and inspired by the proximity principle: "Things that matter are close. Things that are close matter." [3], we consider the borders of the observable space to define the set of objects that can possibly be part of an "application" at any given time-instant for a specific human agent. This view aligns well with the WIMP/direct manipulation paradigm for virtual-world interaction where successful application design (as well as use) depends on keeping the right objects "on screen" at the right time. Drawing from experience in that interaction paradigm, and the human everyday strategy to arrange objects in the real world into places, it is probably reasonable to generalize and expect physical-virtual "applications" that demand or provoke frequent fundamental changes to the observable space to be considered inefficient, confusing, and/or annoying for a human actor.

Applying the Framework

The situative model of physical-virtual space serves at least two purposes: 1) as a conceptual tool for guiding the design of physical-virtual systems in which high-level human perception and everyday human activities are connected, 2) as a basis for physical (and virtual) activity recognition systems that analyze object translation patterns within the spaces.

Up until now we have focused on the second kind of model application in the context of developing a "cognitive prosthesis" in the shape of a wearable computer for people suffering mild dementia[2]. More concretely, the situative space model has been tested as a tool for everyday activity recognition based on how physical objects enter and leave the spaces around the specific human actor's body. The results from the tests (up until now however only simulated in an immersive VR home environment) are encouraging, revealing an activity recognition rate of between 81-91% among 10 household activities after an initial training phase. A paper describing the system and the evaluation in detail is currently in submission elsewhere.

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[1] A first quick-and-dirty attempt is presented in [4].

[2] http://www.cs.umu.se/research/easyadl

Having achieved an acceptable activity recognition rate in the VR environment, we are now implementing a system in the real world based on our findings. Furthermore, and of more relevance to this workshop, we are facing the challenge of modelling human activity in more detail as the "cognitive prosthesis" is intended to act and provide constructive suggestions whenever a problem in performing an activity is likely to have occurred for the patient. In short, we need to formalise what goes on in the "object manipulation" space in Fig. 1.

Relation to Tangible User Interfaces

At the moment we are very interested in two complementary approaches for capturing general characteristics of everyday object manipulation. 1) The modelling of containment relationships between objects (e.g. the book is in the bookshelf; the pen is on the table, the ball is in the bag; etc.), 2) the modelling of internal states of everyday objects (e.g. the oven is on, the glass is full). We have so far been able to develop the system avoiding the "hard-coding" of any particular kind of ontology fixating the meaning of the everyday objects in the system like for instance the one proposed in the Ubisworld project, (www.ubisworld.org). The fact is that the activity recognition system makes no distinction between a fork or a pen, a knife or a book, and will not react as long as they are used by the human actor in the same activity context as in the training phase. We would like to continue on this road and try to not associate meaning to objects and objects' states unless absolutely necessary. The obvious gain is that the activity support system could be applied with no or little modifications to many different activity scenarios. We are searching for a very general and simple object ontology which at the same time allows our system to provide help with enough detail for our target user group and for the activities they are likely to perform. Whether one single ontology extending over all task domains would suffice for providing enough object manipulation detail, or if a set of ontologies is needed (one for each domain, e.g. household activities), is an open issue.

The area of Tangible/Graspable User Interfaces has a tradition (if such a word is allowed for an area so young) of defining simple object ontologies to distinguish between object categories of importance to the particular design domain at hand. "Blocks", "tokens", "constraints", "containers", "tools", "domain objects", and so on. Also, simple models of object relationships are heavily used in this community. Obviously, the real world is more complex than any TUI prototype but do our computer systems monitoring it need to care for all that complexity? The Context Awareness community is certainly assuming that this is not the case. Can Tangible User Interface concepts be used for describing everyday object manipulation? Due to the fact that the translation and manipulation of graspable objects play fundamental roles in human activities, both in everyday settings as well as in interaction with more dedicated TUI systems, we believe so. Exactly how a TUI-inspired model of everyday object manipulation would look, compatible with the egocentric interaction framework outlined earlier in this paper, is an open issue and left for future work. One interesting detail is obvious though: in order to model also direct manipulation of virtual (digital) objects, such a TUI-inspired model would have to encompass also interrelations and state changes taking place with no tangible brick, block, or token in sight. (Any present mouse or keyboard does not count: see the description of the physical-virtual design perspective earlier).

Notes on Our Design Approach

Any design effort (other than perhaps "pure artistic expression") involves the identification of various kinds of constraints that need to be considered as part of the design process. Some are intuitively present and seldom explicitly noted (e.g. gravity in the real world), some are there because empirical evidence points them out (e.g. Fitt's law [1]). Some are embedded in designer's tacit knowledge built up from experience. In any case, although constraints in this

sense at first sight might appear to have a negative impact on the design process (no matter if mechanical, economical, technological, political, psychological, ergonomic or conceptual), a closer look reveals the widely acknowledged fact that they help designers to frame the problem at hand and sometimes even help "driving" the design process towards a solution. Design work performed within explorative branches of the Human-Computer Interaction (HCI) field such as Ubiquitous/Pervasive Computing and Context Awareness, have (for good and bad) prioritized the study and use of constraints stemming from the limitations of new and emerging technology. As a result, at least in part, much of the advances in these fields are of technological nature. With few exceptions (such as some of the work within the Tangible User Interface community, e.g. [2]) even the theoretical work of generalizing and conceptualizing the results seem heavily influenced by currently available technology.
Being designers of Ubiquitous Computing systems ourselves, we admit that developments in the area of sensors and data communication influences the way we move around in our design space. However, we deliberately try to limit that influence in favour for design constraints emerging from other fields related to HCI such as Cognitive Science and ethnographical studies of human behaviour. In order to stay ahead of hardware technology, we also use Virtual Reality (VR) simulations to explore the behaviour of interactive systems that would be hard or even impossible to build with the real-world sensor technology available today. By adopting this design approach we hope to a) arrive to new ways of looking at the exciting kind of human-computer interaction which *de facto* emerges in the shadows of hardware and software technology development, b) identify areas for hardware and software technology improvement which would enable new kinds of personal computing on the basis of other design factors than the ones posed by only sensing and communication technology itself. Our overall aim is to contribute in creating the conceptual design framework(s) for personal everyday computing beyond the PC/PDA/cellular phone of which we believe the emerging post-WIMP[3] HCI field is in desperate need of.

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[3] WIMP – Windows, Icons, Menus, Pointing device.