Position paper submitted to the PERVASIVE2004 workshop "Computer Support for Human Tasks and Activities".

Designing for Physical-Virtual Activities

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1 The Emergence of Physical-Virtual Activities

Computers, embedded in the "background" as well as more obtrusive artefacts (e.g. PCs, PDAs, cellular phones), play an increasingly important role in human activity. However, there are still things that most people would prefer to do "off-screen" in the physical (real) world, such as having parties, reading long text documents, or spending vacation. I argue that there exists a class of activities that are neither physical or virtual, but "physical-virtual" [2]. People frequently do parts of an activity in the physical world (e.g. proof-reading a text document under construction) and parts in the virtual world (e.g. adjusting paragraphs within "the same" document in a word processing environment). This behaviour is likely to become more common. Hence, future environments should be designed with such physical-virtual activities in mind.

1.1 Goal and Approach

For this purpose, I propose a physical-virtual design framework to deal with the gap between the physical and the virtual world[1], and facilitate the exploration of designing information technology for helping human agents bridging it. The assumption is that a reduced physical-virtual gap means less "friction" for physical-virtual activities. Physical and virtual space is modelled together, and automatic mechanisms for synchronising related phenomena in both worlds are offered. By viewing the physical and virtual worlds as one, I believe the chance to *make* them one increases.

2 A Conceptual Framework for Physical-Virtual Design

The need to take into account the physical world when studying and designing for Human-Computer Interaction (HCI) has gained increased recognition for the past 10 years. The proposed physical-virtual design framework rides the same wave of "HCI field expansion" but takes a quite extreme stance by viewing the physical and the virtual world as existing in parallel and of *equal importance* for interaction.

We limit ourselves to activities that a) have a clear meaning, b) are observable by a human agent, and c) are observable by an artificial agent. Although this narrows the scope of the model significantly, e.g. it leaves out pure cognitive and social processes) we believe that for our purposes, the gain in modeling power compensates for it. A dis-

1. Dimensions of the gap between the physical and virtual worlds are explored in [2].

tinction is made between physical, virtual, and physical-virtual activities. The notion of activity is furthermore divided into operations, actions and activities depending on the level of abstraction.

2.1 Outset: Physical, Virtual, and Physical-Virtual Actions

Adopting the physical-virtual design perspective involves abstracting away the classical HCI concepts of input and output devices, giving them a background role as Inter-World Event Mediators (IWEMs). Fig. 1 and 2 illustrate the basic cases of physical and virtual human action (object manipulation). IWEMs are shown as white squares.

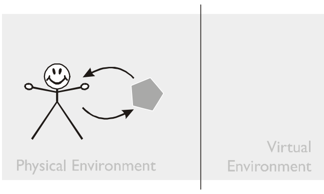


Fig. 1. Physical action [2]

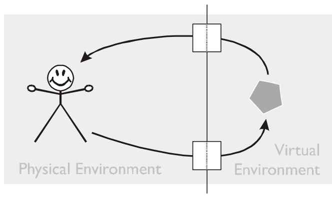


Fig. 2. Virtual action [2]

In order to arrive at a definition of physical-virtual activity I have found it useful to define human border-bridging activity on a lower level of abstraction first:

> **DEFINITION 1:** A *physical-virtual action pair* consists of two actions belonging to the same activity and often time-wise adjacent, where the first action is constrained (by lack of action support in the current environment) or chosen (e.g. based on individual preferences) to be performed in the physical world and the other action is constrained/chosen to be performed in the virtual world, or vice versa. [2]

Physical-Virtual Artefacts. Among physical-virtual action pairs we can sometimes identify one or several information-mediating objects that are subject to indirect or direct human manipulation in *both* actions, objects that transcend the physical-virtual border by being present in both worlds. Such objects are referred to as Physical-Virtual Artefacts (PVAs) and for denoting the presentations of them in the two different worlds, the term PVA manifestation is used. A text document presented in both the physical (e.g. printed on paper) and the virtual world (e.g. within a word processing environment) would serve as a good example of a PVA, where each manifestation affords different kinds of manipulation.

> **DEFINITION 2:** A *physical-virtual action* is an action on a PVA where both the physical and virtual manifestations are directly controlled and/or monitored by the agent. [2]

Fig. 3 and 4 illustrate two possible kinds of physical-virtual actions. Finally, the con-

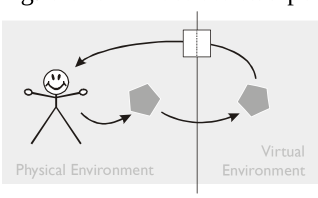


Fig. 3. Physical→ virtual action [2]

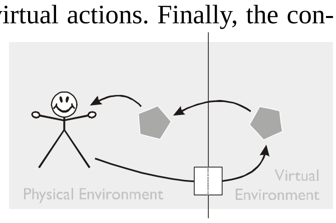


Fig. 4. Virtual→ physical action [2]

cept of physical-virtual activity is defined as follows:

> **DEFINITION 3:** A *physical-virtual activity* is an activity consisting of a sequence of actions containing a) at least one physical-virtual action pair or b) at least one physical-virtual action. [2]

2.2 One Space, One Magnifying Glass

By viewing the physical and the virtual worlds as equally important for human activity, the proposed design framework makes terms with implicit virtual-world bias like "context awareness" become obsolete. It also expands the meaning of "location tracking" (currently having an implicit physical-world bias) to include also space and place in the virtual world. It invites the viewing of the relationship between physical and virtual environments from unconventional angles. For instance, why should not the current (local) state of the virtual world influence how activity in the physical world is interpreted? Could it not be of use for physical-world "applications" to be aware of their virtual-world context? And why is virtual-world location tracking (e.g. web pages browsed by a human agent) not considered when designing interactive environments?

The proposed physical-virtual design perspective is based on a series of world-neutral definitions of space that allow us to disregard whether common human actions such as navigation and object translation take place in the physical or the virtual world. Two models developed so far are briefly presented below.

2.3 A Situative Physical-Virtual Space Model

At any given point in time, a specific human agent is able to (visually) observe only parts of the physical and the virtual world. Furthermore, only parts of these observable "sub-worlds" contain objects that can be manipulated. Thus, in any given situation, three inclusion-related spaces can be distinguished in the physical and the virtual world respectively, as pictured in Fig. 5. While the general "object translation pattern" looks similar for both the physical and the virtual world as to where "hot" and "cold" [4] objects can be found, there are differences when it comes to the frequency and dynamics of object translation. In the physical world, objects often enter and leave the observable subspace in large "chunks" as the human agent navigates in the physical world space, e.g. by leaving one room for another. In the virtual world, by contrast, objects are often moved into and out of the observable subspace one at a time.

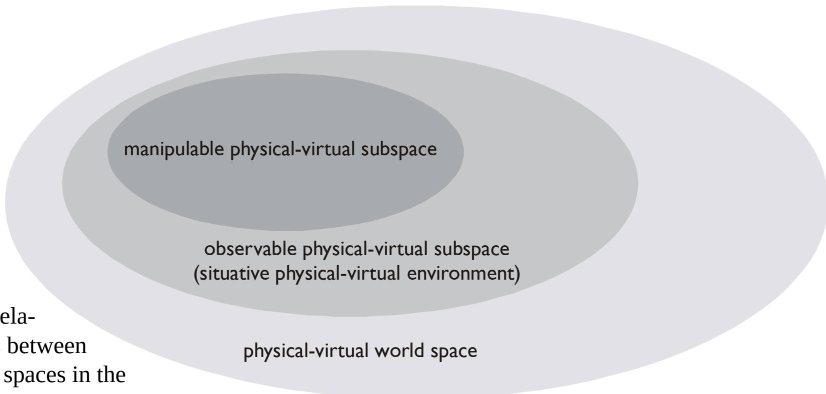
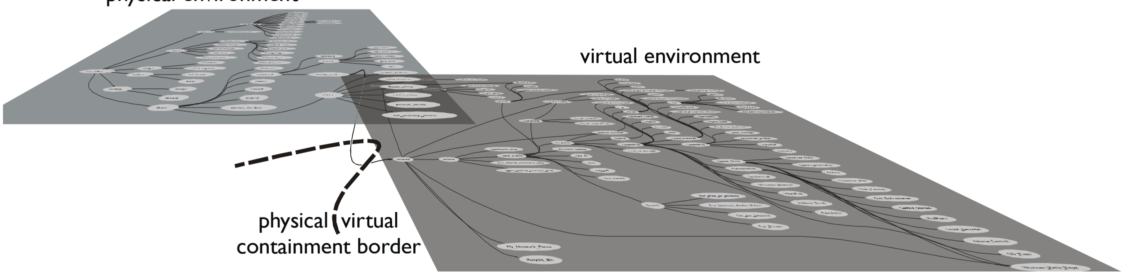


Fig. 5. Relationships between the three spaces in the proposed situative physical-virtual (PV) space model: A small subspace of the physical-virtual world space is observable, and a part of that observable subspace is also manipulable, by a human agent at a given point in time [2]

2.4 A Hierarchical Model of Physical-Virtual Space

Both physical and virtual environments can be modeled as hierarchies based on the objects situated in them and containment relationships between those objects. However, because the physical and virtual worlds typically differ structurally, "containment" cannot mean exactly the same thing in both worlds. Furthermore, in the virtual world, cheap "cloning" of objects as well as independency from laws of nature opens up for a more irregular structure compared to the physical world. Fig. 6 shows a particular physical-virtual environment structured around containment-relationships.

Fig. 6. A physical and a virtual environment visualized as a physical-virtual containment hierarchy. The border between the physical and the virtual world is at the point where the PC display unit physically contains the virtual "desktop" object [2]



3 Magic Touch — A Physical-Virtual Prototype System

Many of the concepts within the physical-virtual design framework have been inspired by, and has inspired, the development of the physical-virtual prototype system Magic Touch [3]. The system is primarily focused on enabling the definition of PVAs and to mediate basic manipulation of physical PVA manifestations (e.g. paper documents) to their virtual counterparts (e.g. web pages). Fig. 8 shows the conceptual system architecture, Fig. 9 shows the wearable object identification and location tracking unit, and Fig. 10 shows a visualisation of the real-world office environment in which the system is installed, based on containment relationships between physical objects.

4 The Physical-Virtual Framework and Activity-Centric Design

I believe that when moving from a classical software application-centric view towards an activity-centric view of HCI settings (as proposed in [1]), one would gain in modelling power by incorporating relevant parts and states of the physical world. If done properly, physical-world and virtual-world prerequisites for successfully performing a specific physical-virtual activity (i.e. all necessary physical and virtual tools and data are available) can be modelled in a straight-forward fashion. If computing systems would maintain such physical-virtual models they could suggest alternative ways of performing tasks depending on available resources, *across the physical-virtual border.* The system could suggest to substitute a missing virtual object with an available physical one, or give hints to the human actor on ways of performing an intended activity

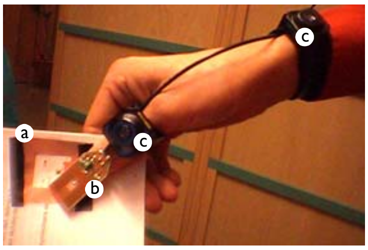


Fig. 9. Magic Touch PVA Manipulation Tracker v.0.51 in action. The photo shows (a) an RF/ID tag attached to a paper document, (b) a stiff antenna, and (c) position transmitters [2]

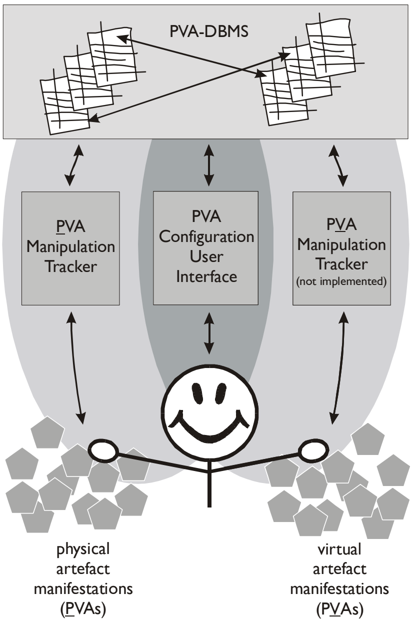


Fig. 8. Magic Touch conceptual system architecture. The PVA-DBMS linking the physical (left) and virtual (right) environments together by keeping track of artefact manifestation changes done by the human agent in any of the two environments [2]

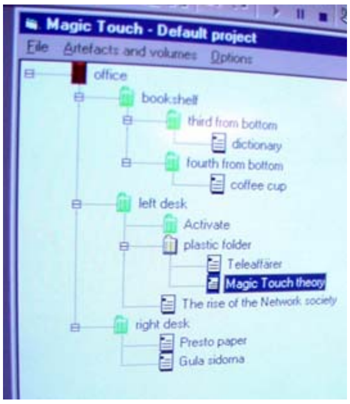


Fig. 10. Parts of the PVA Configuration UI of Magic Touch 1.0 showing a hierarchical virtual representation of objects in a physical environment based on containment relationships [2]

more efficiently by switching from the physical to the virtual world or vice versa. Incorporating real-world objects and phenomena into the interaction model also opens for an intuitive inclusion of mechanisms and phenomena commonly referred to as "interaction context" in the Context-Awareness communities. In fact, "context" phenomena would no longer be external to the activity, but simply part of it.

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