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Physical-Virtual instead of Physical or Virtual — Designing Artefacts for Future Knowledge Work Environments

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1 Designers' Perspective on Physical and Virtual Environments — Criticised

Among designers of knowledge work environments (KWEs) it is common to distinguish between those involved in designing the virtual part (software designers) and the physical part (office tool manufacturers, architects etc.) of the environments. Recent advances in user interface technology, for example (Fitzmaurice et al. 1995, Harrison et al. 1998, Ishii and Ullmer 1997, Mackay 1998, Rekimoto 1997) evokes the question whether this distinction is really a suitable starting point when designing future KWEs. As physical things get connected to virtual representations and virtual objects get physically augmented user interfaces, artefacts are no longer either physical or virtual. They are physical-virtual. Thus, to divide the environment in a physical and virtual part is a convention which limits design ideas, as new enabling technology (tiny radio-based digital networks, wireless motion tracking systems, digital ID-tags etc.) emerge.

1.1 Knowledge Workers' Perspective on Physical and Virtual Environments

In contrast to the sharp separation of the physical and virtual environment usually assumed by KWE designers, knowledge workers conceptually find themselves *between* the physical environment (for instance an office) and the virtual environment (usually provided by a personal computer). In order to work efficiently, to feel comfortable, or to conform to standards within their organisations, knowledge workers alternate between the two environments depending on the task at hand. This alternating behaviour involves bridging the physical-virtual environment gap, incurring costs in terms of cognitive effort, time, and money.

We propose a theoretical perspective intended to encourage designers to focus on functionality regardless if the artefact is to be implemented in the physical or vir-

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tual environment. The proposed perspective encourages design of artefacts that exist in both environments at the same time; physical-virtual artefacts (see Fig. 1).

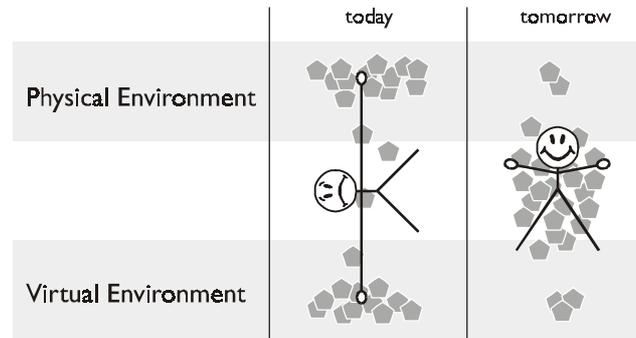


Figure 1: Vision and goal: Artefacts that are both physical and virtual at the same time.

2 Characteristics of Physical and Virtual Environments

Although people increasingly use IT in both traditional and more modern activities, the physical environment has yet been difficult to replace entirely. We assume that in the foreseeable future, people will continue to perform activities in both the physical and the virtual environment. By presenting unique affordances and constraints (Norman 1988) to the knowledge worker acting in the environments, as well as to the different artefacts present within them, the two environments support different kinds of activities. We can identify some characteristics distinguishing the two environments from each other (Table 1).

Environment	Physical	Virtual
perceptual feedback (tactile, visual, auditive)	very high	low
social interaction support	very high	low
independency on physical location	low	high
support for distribution of artefacts (sending, copying, publishing)	low	very high
symbolic manipulation support	low	very high
support for reversible operations (UNDO)	low	high

Table 1: Some characteristics of physical and virtual environments.

This list presents some general environmental characteristics tuned to our specific focus on knowledge work and is by no means complete or always applicable.

3 The Physical-Virtual Environment Gap

Traditionally, knowledge workplaces equipped with personal computers tend to create a significant gap between the virtual environment offered by the computer

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system(s) on the one hand, and the surrounding physical environment on the other. This environment gap makes it costly (1) to maintain a coherent cognitive model of the physical-virtual KWE, and (2) to transfer information entities (e.g. documents) between the two environments.

In this paper we will relate the costs to (1) how much of a 'productivity bottleneck' the cost for performing the specific activity is, in comparison to other knowledge work tasks, as well as (2) what today's and soon-to-come technology can or should be able to offer the knowledge worker in order to minimise them.

3.1 Cognitive Incoherence Between the Environments

Knowledge workers have to build and maintain a mental model of the working environment, its contents, and the task. Two factors making this difficult today are:

- metaphoric incoherence — Conceptually corresponding physical and virtual artefacts in the environments differ in behaviour and appearance even if their basic characteristics and utility are the same (Norman 1988).
- identity incoherence — The mappings between equivalent artefacts in the physical and virtual environments are weak.

3.2 Costs for Transferring Information Entities between the Environments

Transfer costs for overcoming the physical-virtual environment gap can take many shapes, for example:

- time — The transfer process is time consuming.
- cognitive effort — The complexity of bridging the gap demands considerable cognitive work, distracting from more creative knowledge work activities.
- money — The equipment or manpower needed is expensive.

3.3 The Design Error to Forget About the Physical-Virtual Environment Cycle

Current design of information entity embodiment (e. g. text documents) present in physical-virtual environments does not seem to consider the fact that knowledge workers perform their work in both environments and that there is no final destination environment for information entities. In fact, in many kinds of knowledge work situations, the destination is the physical-virtual environment and *not* one or the other. You never know how your information entity will be used (or re-used), and parts or the whole entity might travel back and forth between the environments many times while it is used by other knowledge workers.

4 The Physical-Virtual Design Perspective

We believe that by introducing a kind of artefact that to largest extent possible supports activities in both environments (see Fig. 1), the physical-virtual gap will decrease. Based on previous considerations of incoherence problems and transfer costs, we can define some characteristics that these artefacts should possess:

Definition: A physical-virtual artefact is an abstract artefact that (1) is instantiated in both the physical and virtual environment, where (2) these instantiations to a

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large extent utilize the unique affordances and constraints that the two different environments facilitate, and finally (3) where one instantiation of a specific physical-virtual artefact is easily identified if an equivalent instantiation in the other environment is known.

4.1 How to make $1 + 1 = 1$

In order to give the knowledge worker a uniform conception of the physical-virtual artefact, we believe that it is more important to create a tight coupling between the instantiations (decreasing the identity incoherence) as required by part 3 of the definition, rather than to give them similar perceptual appearances (metaphorical coherence). This is because to fully take advantage of the unique affordances and constraints in the environments, as required by part 2 of the definition, the instantiations most probably have to differ in appearance and functionality. Thus, artefact designers must, to some extent, renounce the use of similarity metaphors and instead increasingly afford a uniform view of the artefact by other means, e.g. by maintaining a tight coupling between its instantiations. The instantiations should complement each other rather than look the same.

4.2 Categorising Physical-Virtual Artefacts

The definition of physical-virtual artefacts is not intended simply to divide artefacts within knowledge work environments into two distinct sets (physical-virtual and not physical-virtual). Instead, we believe that it can be interesting to view also artefacts not perfectly satisfying the definition, from a physical-virtual perspective. The definition should be treated as an ideal that artefacts can comply with to a smaller or larger degree. A simple categorisation of common artefacts in knowledge work environments can be to make distinctions between information entities, tools and autonomous agents/processes (Fig. 2). One example of existing physical-virtual tools is the common mouse interaction device (Fig. 3). Another example is compact disc players mounted in PCs allowing users to choose between a physical or virtual UI.

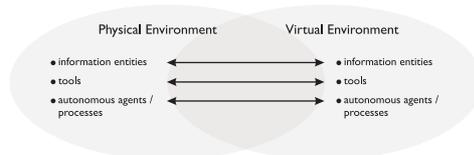


Figure 2: Three categories of physical-virtual artefacts in knowledge work environments.

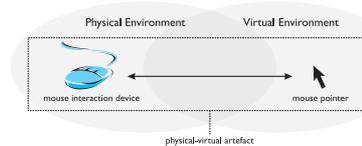


Figure 3: A physical-virtual artefact (tool) and its' two instantiations.

5 Related Work

This work is to a large degree inspired by research prototypes like (Fitzmaurice et al. 1995, Harrison et al. 1998, Ishii and Ullmer 1997, Mackay 1998, Rekimoto 1997) that in different ways and for different purposes try to utilize characteristics

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of the physical world in their design. However, to our knowledge, there is no unified design-theoretical approach that focuses on the physical-virtual environment integration from a general artefact perspective, such as the one presented.

6 Conclusions

We believe that the physical-virtual design perspective outlined in this paper expands the possible design space to include both physical and virtual functionality, facilitating development of artefacts that more or less automatically decrease the costs for knowledge workers to cope with the physical-virtual environment gap.

7 Future Work

A KWE based on the physical-virtual design perspective will be set up and evaluated during 1999. Physical-virtual artefacts to be implemented are based on a scenario not presented here because of space limitations, and include: physical-virtual documents (information entities), a physical-virtual mail handler (agent), a physical-virtual paper basket (tool), and a physical-virtual search engine (tool). A field study of knowledge workers in Swedish industry is scheduled for summer 1999, aiming to (1) acquire knowledge about the extent of the physical-virtual environment gap and (2) find application areas for new physical-virtual artefacts.

8 Acknowledgements

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