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Object Location Modeling in Office Environments — First Steps

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Abstract. In this position paper we briefly present our application of location modeling onto office environments, in the context of our general goal of designing physical-virtual knowledge work environments.

1 Introduction

In a world where humans increasingly find themselves in a state of information overload, location data can serve as valuable input to computer systems for filtering out irrelevant information based on the current physical context of the user. This is based on the assumption that there is a relationship between the user's interest and her/his physical location. Similarly, the location of *objects* can say a great deal about what the objects mean to the person that placed them in their particular locations as well as how they are perceived by others. In this position paper we describe our research efforts in designing integrated physical-virtual environments where object location tracking is an important part of the underlying architecture. However, we are only in the beginning of understanding how this location data best can be used to facilitate and support the physical activities performed by the user. We believe that object location tracking has the potential of enabling services beyond information filtering. The remainder of the paper will discuss the underlying location model that the Magic Touch system uses to represent physical activities in a virtual environment as well as point to some open questions related to location modeling to be addressed in future work.

2 Designing Physical-Virtual Knowledge Work Environments

Definition: A knowledge worker is a person principally concerned with data, information, and knowledge as working objects, often working with these in both the physical world and the virtual (digital) world, and sometimes in the borderland between them. Common work tasks are to create, search, refine, and mediate data, information, and knowledge [2] based on [3] and Kidd [4]. Since aspects of knowledge work are present in almost all human activity, we do as designers of knowledge work environments currently focus on supporting certain kinds of knowledge work, namely activities in office environments, in order to reduce the research scope. In offices, people tend to organize their physical environment based on general parameters such as how objects relate to other objects, how often they are used, the urgency of dealing with issues connected to them, personal interests as well as personal preferences for how to organize their workspace [6].

Seeing Wellner's DigitalDesk [10] as a starting point, there has been a continuous interest in merging the physical and virtual worlds in office environments and in more specialized settings such as [1, 5].

Although knowledge work activities often involve extensive use of the virtual environments that modern information technology provide, significant working time is spent on activities in the physical environment as well. However, knowledge work environments equipped with personal computers tend to create a significant gap between the virtual environment offered by the computer system(s) on the one hand, and the surrounding physical environment on the other [7, 9].

2.1 A Physical-Virtual Design Perspective

In order to overcome this gap, a perspective for design and analysis of integrated physical-virtual environments is currently under development, based on analysis of differences and similarities between physical and virtual environments, such as [1, 7]. This physical-virtual design perspective emphasizes a holistic view on the design of knowledge work environments and the objects within them, in order to break loose from traditional distinctions made by designers of software, electronics hardware and architecture [7]. A core concept within this design perspective is the concept of Physical-Virtual Artefacts (PVAs), things that consist of both a physical and virtual representation, tightly linked to each other. Changes done on the physical or virtual representation of a specific PVA is assumed to immediately change the state also of the other. Notation: While PVA refers to both instantiations of a PVA (that is, the PVA as whole), <u>P</u>VA refers to the physical instantiation of a specific PVA and P<u>V</u>A refers to the virtual instantiation of a specific PVA.

2.2 Magic Touch

Physical-virtual homomorphism is assured by a computer system, Magic Touch [8], which recognizes any alterations on PVA instantiations and consequently performs the appropriate update to the other corresponding instantiation (see Fig. 1.). Fully developed (it is still under development), this system will make use of a large amount of

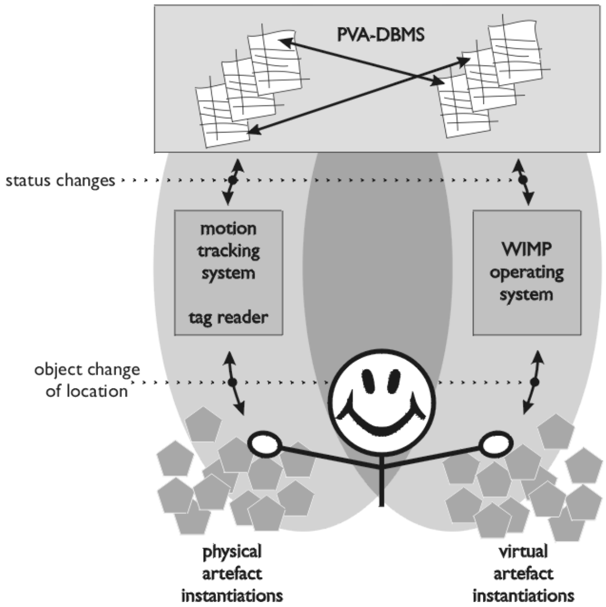

Fig. 1. Magic Touch basic architecture [8]

physical and virtual activity data to be used as input to user modeling and object (PVA) modeling algorithms.

Technically, the object location tracking is performed by a combination of RF/ID, infrared and ultrasound technology based on a small wearable unit placed on user's hands, as described in [8].

3 Location Modeling

Almost all physical activities performed by humans involve moving things from one place to another. Sometimes it is a matter of millimeters, sometimes its about thousands of kilometers. Sometimes its about moving parts of an object while at other times collection of objects are moved all at once. We have found it useful to differentiate between two different kinds of object manipulation: *Inter*- and *intra*-manipulation.

- Inter-manipulation stands for activities that change the relationship between a specific object and other objects.
- Intra-manipulation is manipulation of a specific object that changes that objects internal state, not necessarily affecting the relationship between the manipulated object and the others.

Currently focused on inter-manipulation, the Magic Touch system registers PVAs' new locations in a database, as soon as they are moved from one location to the other within the tracked environment. Thus, the system can be said to maintain a low-level location model of all PVAs. In addition, the user is given the possibility of defining three-dimensional spaces in the physical environment, "active volumes", and to give these spaces names. The user can also assign virtual functions to the active volumes so that activities within a specific volume triggers an application to start or a certain operation to be applied, based on the activity. At the time of writing, the only activity that can be assigned functions is the activity of putting a PVA into an active volume. As an example, the user could define an active volume called "inspection" that automatically displays PVAs that corresponds to any PVA that is put into the active volume.

Fig. 2. shows a simple virtual representation of a physical office environment. The

user has defined active volumes for some furniture in the office including bookshelves and desks. Each active volume is represented as a folder in the hierarchical tree structure. PVAs and active volumes placed within active volumes become children to the folder that represents the active volume. This model, defined by the user and maintained by the system, allows the system and the user to communicate about PVA locations and relationships between PVAs, based on the names that the user has given them. Thus, this tree structure represents a higher-level location model of the physical space compared to the coordinate-based mentioned earlier. E.g., as a result of a search operation, it is more suitable for the user to learn that the phone book is on the second bookshelf rather than on coordinates 23, 289, 119.

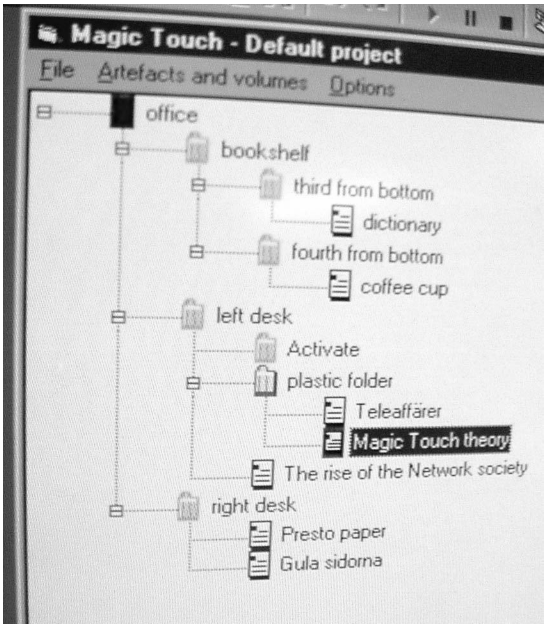

Fig. 2. A physical office represented as a tree structure [9]

We have also implemented a Virtual Reality-based visualization of the physical space that, however, from a modeling view is identical to the one represented in Fig. 2.

3.1 The Physical World as a Tree

Is it reasonable to model the physical world as an hierarchically organized collection of invisible volumes and artefacts contained by them? For our purposes, having the goal of modeling user's way of organizing their knowledge work environments, we believe that it is a powerful and yet simple modeling approach.

A strength is that the level of model granularity, or the "volumisation", 1) is controlled and configurable by the user, and 2) is allowed to be different in different parts of the tracked physical environment. Thus, physical places where high-precision/short-movement activities are of interest (e.g. a wall-hung geographical map having markers attached to it for the representation of company offices throughout the world) can be mixed with spaces where detailed modeling is of little use (e.g. in open air where physical bodies are not supported by a force perpendicular to gravity). This model does not compromise a simple three-dimensional grid because the active volumes can be of different size and be nested.

3.2 Problems and limitations:

- **Clashing volumes.** Spaces only partially enclosing each other are hard to handle. We have found it necessary to constraint active volumes to either spatially fully enclose each other or to be completely disjunctive. If this restriction is not followed, PVAs can get several representations in the same tree structure which for most applications probably would confuse the user.
- **Context dependency.** Naming of the active volumes is task/perspective dependent. Certain physical locations mean different things in different context. For environments used by more than one person and/or for more than one purpose this can be limiting. For our purpose we don't see any big problems since offices, at least as regards the physical organization of objects, are mainly used by one person only.
- **Model construction overhead.** To define active volumes introduces overhead since three corners of the volumes have to be pointed out and the volume should be given a name. We have tried to at decrease the possible distraction from the work by giving the active volumes default names at the time of definition. Nevertheless, under normal working conditions we expect office workers to spend most time with defining the volumes in an initial stage so the overhead in a longer perspective is assumed to be relatively low.

3.3 Possibilities for Improving Interaction using Location Modeling

Gathering and interpreting information about user activities in knowledge work environments has the potential to improve knowledge work environments in many ways. A few potential location-modeling-based contributions could be:

- Information/functionality filtering, allowing for minimalistic interaction styles using small interaction devices (small screens, few buttons), possibly wearable
- Re-design of the working environment with respect to Euclidian, topological and temporal aspects to better suit most frequent or most time/space/cognition-intense tasks
- Incitement for the creation of knowledge work tools that rationalize (compresses, compiles) recurring object-use sequences by providing tool functionality applicable on all objects at the same time instant
- On-demand organization suggestions where the system proposes suitable place-

ment of new/altered objects based on their similarity with objects already existing in the environment. This presupposes that semantic analysis of the existing objects in the environment has been performed (relatively cheap if the objects are PVAs since then it is enough to analyze the already digitized PVA).

- The users's spatial organization of PVAs can be analyzed from a similarity perspective and connections between objects that otherwise would be impossible to infer since it is based on implicit user knowledge not perceivable by the system.

4 Conclusions and Future Work

We have presented our initial attempts to model office environments based on location changes of physical objects. Extensive refinements and additions to our model is left for future work.

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