Magic Touch: A Simple Object Location Tracking System Enabling the Development of Physical-Virtual Artefacts in Office Environments

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Abstract: A novel method for tracking physical activities is presented. The method is based on the assumption that all changes to the physical environment are done by users themselves, and that these actions can be tracked using wearable computer technology placed on human hands. Various limitations of the proposed method are discussed. Acknowledging these limitations, a range of possible applications are presented, e.g. a set of Physical-Virtual Artefacts intended to decrease the gap between the physical and virtual environments within offices. Also, some aspects of the modelling of user actions in office environments are discussed.

Keywords: Augmented reality; Context awareness; Graspable user interfaces; Knowledge work support; Situated interaction; Wearable computers

1. Tracking Objects

One straightforward way of getting input from physical user activities in office environments is to track location and location changes of objects. In other words to reduce "activities" to "object change of location". Of course, this simplification implies considerable loss of other kinds of information, including for instance mental state and movements of the user alone, but we believe that it is a good starting point for further improvements. Accepting these limitations, the parameters of interest are:

- Exactly what object is being moved?
- To what new location?

1.1. Some available technology and methods

One obvious solution is to let all objects in the environment carry position transmitters, giving both parameters accurately and continuously. Drawbacks are that the system is expensive if you want to track many objects, and the identification tags can be fairly large. Another method is to put a camera in the ceiling and to attach visual tags onto the objects. These tags and their location are interpreted and calculated through analysis of the camera image [1]. In this case the tags are considerably cheaper compared to the other approach since it is possible to print them out on an ordinary printer. Drawbacks include the necessity of free line-of-sight between the camera and the tagged objects and that the tags themselves could become fairly large when tracking many objects.

2. A More Indirect Method

While searching for a suitable tracking method we discovered a fundamental fact: objects in office environments don't move by themselves! They move *when they are moved by users' hands*. Put another way, an object stays where it is until the user grabs it in one or two hands, moves the hand(s) to a new location and drops the object. Based on this insight, we developed another object location tracking method that, at least for our purposes, probably will be more suitable than the other two tracking approaches mentioned. However, the system is currently under development and evaluation has to be performed in order to substantiate our belief.

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Fig. 1. One of the user's hands holding a tagged paper document.

As illustrated in Fig. 1, the object location tracking system consists of (1) an office environment containing RF/ID-tagged artefacts, (2) wearable wireless tag readers, placed on each of the user's hands, identifying any tagged object the user takes in their hand, and (3) a wireless location transmitter always aware of the positions of the user's hands.

The advantage of using RF/ID tags for our kind of application instead of similar solutions such as barcodes is thoroughly discussed by Want et al. [2].

As soon as the user's hand nears a tagged object, it is identified. If the user moves their hand and the reader still can read the tag it means that the user has grabbed the tagged artefact. When the tag is no longer readable, the user must have dropped the artefact, and the location of the user's hand at the point when the tag was last readable is regarded as the new location of the artefact.

Having the development of Physical-Virtual Artefacts[1] (PVAs) as an overall goal, the above described object location tracking system can be integrated with a PVA Database Management System (PVA-DBMS) where each artefact instantiation, no matter physical or virtual, has an entry as shown in Fig. 2.

[1]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 large extent utilise 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 [3].

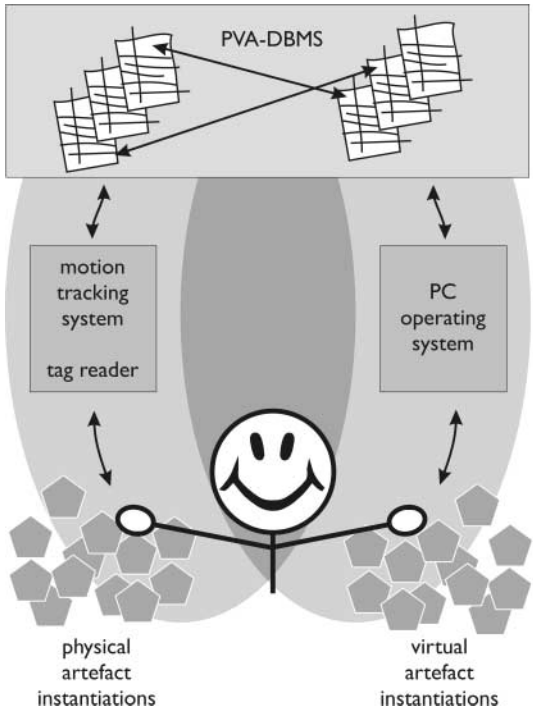

Fig. 2. Magic Touch architecture outline. The PVA-DBMS linking the physical (left) and virtual (right) environments together by keeping track of artefact instantiation changes done by the user in any of the two environments.

2.1. Limitations

With small and powerful enough readers and motion tracking technology we believe that this method would deliver location changes of objects accurately and non-intrusively. However, the system relies on several limiting assumptions. Here are the most evident:

- All objects that are to be tracked have to be tagged. (The proposed system shares this limitation with the other systems, however.)
- No tagged object is allowed to change its own position by itself unless it is able to communicate the new position to the system by itself.
- The user does not drop an artefact "in the air". If so, the system will store an incorrect height location.
- The user moves only one artefact at a time. If many tagged artefacts are to be moved at once, some kind of "multi movement mode" has to be entered explicitly.
- The user always moves artefacts directly with the hands and does not use any kind of tool to push or carry the artefacts "from a distance".

- Only users who carry the wearable system equipment are allowed to move artefacts in the environment.
- The position of an object is based on the tag position, that is, one point in space. For small artefacts, it is a reasonable approximation, for larger objects the position approximation error will be more evident.

Some of the limitations mentioned above can be eliminated or reduced by the introduction of additional mechanisms, sometimes also involving explicit user activity.

3. In Search of Meaning

Apart from the fact that the proposed system could serve as a tool for researchers interested in the physical behaviour of knowledge workers, *automatised* user modelling could of course be used to enhance the performance of the system itself. One fairly easy way to extract contextual cues would be to consider time and place of physical user activities.

Artefacts that are used (in our simplified version, *moved*) frequently can be distinguished as being generally useful and important for everyday activities. Artefacts that are less frequently used but then perhaps often at the same time, or often placed close to each other, could be considered as being related to each other. Implicitly acquired knowledge such as this would make it possible for the system to create and maintain a self-organised artefact relationship model, a kind of semantic network. Among other things, this model could help in solving interaction ambiguities and/or let the system suggest relevant material that the user might have overlooked. Another feature of this model is that it reduces the need for explicit definitions of artefact relationships and categorisation, which is a task connected to significant cognitive effort [4]. It also opens up for a less predefined and a more individual organisation and interaction style compared to the kind of well-structured dialogue-driven human-computer interaction common today.

Based on previous activity sequences the system could also try to predict what artefact or what system functionality the user probably would like to get access to in the following activities, improving work efficiency.

4. Application Ideas

- A physical-virtual (PV) search engine enabling search not only for virtual artefact instantiations but also for physical ones. The system points out where in the physical environment the user left the artefact the last time it was moved.
- A PV mail box handling both physical and virtual mail in a similar fashion.
- A PV paper basket handling and synchronising discarding of PV documents.
- Tele-presence: by visualising the PVA-DBMS and enabling the access to the visualisation through the Internet, users can visit VR versions of their physical offices from any place via an Internet connection.
- PV containers: physical instantiations of PV containers (e.g. document folders) can be linked to sets of virtual artefact instantiations and vice versa, making it possible to "keep" both physical and virtual artefact instantiations in the same container, physical or virtual.
- PV stacks: the user can explicitly define, or the system can implicitly infer (see previous section) stacks or piles of objects that can later be referred to as a physical instantiation of a PV container. Among other things, this could eliminate the necessity of moving one object at a time.
- Active volumes: volumes in physical space that the user explicitly has assigned some "meaning". The difference compared to the PV stacks and containers is that the defined volume is physically just empty space. The user could, for instance, define one part of the physical desktop as being a mail outbox or a paper basket. End-user programming would tie appropriate system actions to each active volume in a similar fashion as in Want et al. [2].
- "Magic memory" allowing backtracking of past user actions, and limited UNDO facilities.
- "Virtually filled" physical artefact instantiations. If the proposed system is combined with a motion tracked head mounted display (HMD), users can handle blank papers, order them in piles, bookshelves, etc. while the actual contents of the papers is projected virtually.

5. Current Development Status

A prototype Magic Touch physical-virtual knowledge work environment including a wearable radio-based (RF/ID) tag reader, motion tracker and PVA-DBMS has been set up. Evaluation and improvement activities are planned.

5.1. Hardware limitations

Small RF/ID-based tag readers have a maximum reading distance of about 2cm depending on tag types. A reading distance of 5–10 cm would be desirable. On the other hand, larger reading distance would increase the possibility of confusing tags.

6. Related Work

Seeing Wellner's DigitalDesk [6] as a starting point, there has been a continuous interest in merging the physical and virtual worlds in office environments and in more specialised settings [7,8]. Compared to the DigitalDesk, the proposed system Magic Touch covers a whole office rather than a desk. More recent sources of inspiration to the present work have been the research done on Graspable [5], Tangible [9] and Manipulative User Interfaces [10]. One major difference between these systems and the proposed one regards how or rather *where* the physical objects (common terms are "Bricks", "mediaBlocks" or "Phicons") are identified. While in the former systems they are identified by tag readers mounted on a set of designated "physical-virtual docking stations", the number of tag readers needed in Magic Touch is never more than two, both attached as wearable wireless devices on the user's hands. This difference also holds for Want et al. [2] where they, although using RF/ID tags, attach the readers on portable computing devices rather than hands and furthermore don't combine the identification mechanism with motion tracking of these devices as in Magic Touch.

7. Conclusions

In this extended abstract we have presented an outline of a system architecture for integrated physical-virtual knowledge work environments [3], Magic Touch. By tracking simple knowledge work actions like the changing of artefacts' locations we believe that we can integrate and enrich the working environment as a whole. By tracking user hands only, and by tagging physical objects, we believe that the system becomes more affordable and powerful than known alternatives for the given application area. However, the system is not yet fully implemented and although it has potential to enable many interesting new applications, apart from generally integrating physical and virtual environments, the system has to be evaluated in practice.

Acknowledgements

Thanks to Lars-Erik Janlert, other colleagues and students at the Department of Computing Science, The FIOL Consortium (Ericsson, Telia, SITI, CUT), HUM Lab.

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