

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

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TRACKING OBJECTS

One straight-forward 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?

Some Available Technology and Methods

One obvious solution is to let all objects in the environment carry position transmitters, whose signals are received by a motion tracker system. Such an approach gives both parameters accurately and continuously. Drawbacks are that the system is expensive if you want to track many objects, and the identification tags are at least to date fairly large. Another method is to put a camera in the ceiling and to attach visual tags, showing unique graphical patterns, to the objects. These patterns and the location of the tags are interpreted and calculated through analysis of the camera image [9]. 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 become fairly large if you want to identify many objects.

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 in 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 which at least for our purposes probably will be more suitable than the other two mentioned tracking approaches. However, the system is currently under development and evaluation has to be performed in order to substantiate our belief.

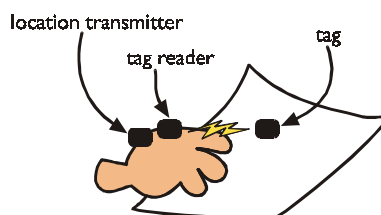


Figure 1: One of the user's hands holding a tagged paper document.

As illustrated in Figure 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 her/his 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 other similar solutions like bar-codes is thoroughly discussed by Want et al. [10].

As soon as the user's hand comes close to a tagged object, it is identified. If the user moves her/his 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 Artefacts¹ (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 Figure 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 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 [8].

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”, letting it fall down to its final location. 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”. This would disable the identification mechanism since the tag reader has a limited reading range.
- Only users that carry the wearable system equipment are allowed to move artefacts in the environment. If non-tracked user hands are active in the environment the system’s artefact location database will become incorrect.
- 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 at least reduced by the introduction of additional mechanisms, sometimes also involving explicit user activity.

IN SEARCH FOR MEANING

Apart from the fact that the proposed system could serve as a tool for researchers interested in 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 perhaps often at the same time instant, 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-organized artefact relationship model, a kind of semantic network. Among other things, this model

could help 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 [6]. 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 following activities, improving work efficiency.

APPLICATION IDEAS

Having discussed the basic parts and ideas related to the Magic Touch system, here are some examples of possible artefacts and applications:

- 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 it 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 enable the access to the visualisation through the Internet, users can visit Virtual Reality versions of their physical offices from any place providing 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. [10].
- “Magic memory” allowing backtracking of past user actions, and limited UNDO facilities. By just giving the system a point in the past time, it can (at least as a visual-

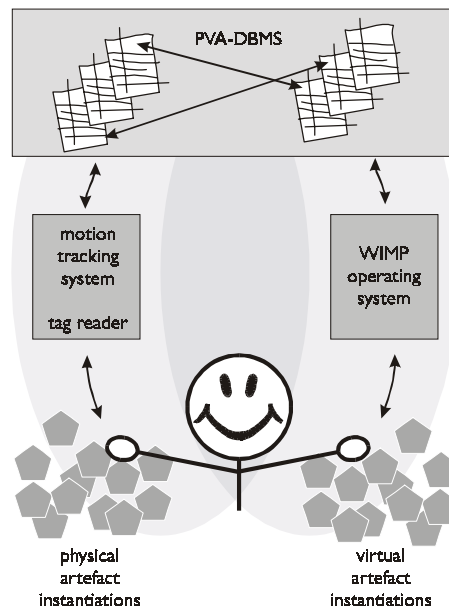


Figure 2: Magic Touch architecture outline. The PVA-DBMS linking the physical (left) and virtual (right) environments together by keeping track of artefact instantiation changes done by the user in any of the two environments.

isation) reconstruct it, showing location and status of each physical and/or virtual objects at that particular time instant.

- “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. In this case, the physical artefact instantiation (the paper) provides the tactile and spatial feedback while the content is provided by the virtual instantiation in the same fashion as a media-Block [2]. Benefits would be better system control of artefact status. Drawbacks include more things to wear and decreased visual ergonomics.

CURRENT DEVELOPMENT STATUS

A wearable wireless radio-based (RF/ID) tag reader is being developed at the time of writing. A complete Magic Touch physical-virtual knowledge work environment including a wireless motion tracker and a PVA-DBMS is planned to be set up and developed during spring 2000. Evaluation is planned to take place during autumn 2000.

Hardware Limitations

Current hardware limitations include:

- Limited motion tracking precision. Suitable systems have a precision of around 2-3 cm in xyz directions
- Small RF/ID-based tag readers such as the one used in this project currently have a maximum reading distance of about 2 cm depending on tag types. To work well, a reading distance of 5-10 cm would be desirable. On the other hand, larger reading distance would increase the possibility of confusing tags.

RELATED WORK

Seeing Wellner's DigitalDesk [11] 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 [1, 5]. 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 [2], Tangible [4] and Manipulative User Interfaces [3]. 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. [10] 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. The support for searching artefacts in physical environments, which is one of the possible applications of the proposed system, has some similarities with the InfoClip [7] solution. However, InfoClip does not involve any centralised knowledge database for where artefacts are located.

CONCLUSIONS

In this extended abstract we have presented an outline of a system architecture for integrated physical-virtual knowledge work environments [8], 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 of enabling many interesting new applications, apart from generally integrating physical and virtual environments, the system has to be evaluated in practice.

REFERENCES

1. Arias, E., Eden, H., & Fischer, G. Enhancing Communication, Facilitating Shared Understanding, and Creating Better Artifacts by Integrating Physical and Computational Media in *Proceedings of Designing Interactive Systems (DIS 97)*, ACM Press.
2. Fitzmaurice, G.W., Ishii, H. and Buxton, W. Bricks: Laying the Foundations for Graspable User Interfaces, in *Proceedings of CHI'95*, ACM Press, 442-449.
3. Harrison, B.L., Fishkin, K.P., Gujar, A., Mochon, C., and Want, R. Squeeze Me, Hold Me, Tilt Me! An Exploration of Manipulative User Interfaces, in *Proceedings of CHI '98*, ACM Press, 17-24.
4. Ishii, H., and Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, in *Proceedings of CHI'97*, ACM Press, 234-241
5. Mackay, W. E., Fayard, A.-L., Frobert, L., & Médini, L. Reinventing the Familiar: Exploring an Augmented Reality Design Space for Air Traffic Control, in *Proceedings of CHI'98*, ACM Press, 558-565.
6. Malone, T. (1983) How Do People Organize Their Desks? Implications for the design of office information systems, in *ACM Transactions on Office Information Systems*, 1(1), 99-112, January 1983.
7. Mori, H., Kozawa, T., Sasamoto, E., & Oku, Y. A Computer-Augmented Office Environment: Integrating Virtual and Real World Objects and Behavior, pp1065-1069 in *Proceedings of HCI International'99*, Lawrence Erlbaum, ISBN 0-8058-3392-7.
8. Pederson, T. Physical-Virtual instead of Physical or Virtual — Designing Artefacts for Future Knowledge Work Environments, pp1070-1074 in *Proceedings of HCI International'99*, Lawrence Erlbaum, ISBN 0-8058-3392-7.
9. Rekimoto, J. Augmented Reality using the 2D matrix code, in *Interactive Systems and Software IV*, Kindaika-gaku-sha, pp. 199-208, 1996. (In Japanese.)
10. Want, R., Fishkin, K., Gujar, A., & Harrison, B. Bridging Physical and Virtual Worlds with Electronic Tags, *Proceedings of CHI'99*, ACM Press, 370-377.
11. Wellner, P. Interacting With Paper On the DigitalDesk, in *Communications of the ACM* 36, 7 (July 1993).