Bridging Physical and Virtual Worlds with Tagged Documents, Objects and Locations

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INTRODUCTION

A compelling and provocative vision of the future was presented in Pierre Wellner's video and article on the Digital Desk [8, 9]. Physical office tools such as pens, erasers, books, and paper were seamlessly integrated (or at least almost seamlessly!) with computational augmentation and virtual tools, using projection and image processing. His work, and now our most recent efforts (reported in this paper and [1, 3, 5]), are directed at more seamlessly bridging the gulf between physical and virtual worlds; an area which we believe represents a key future path for the design of user interfaces. A goal of this work is to seamlessly blend the affordances and strengths of physically manipulatable objects with virtual environments or artifacts, thereby leveraging the particular strengths of each.

The goal of this video is to visually present scenarios of a number of working physical prototypes we have designed and built which computationally augment everyday objects to support casual interaction using natural manipulations. Unlike previous work [2, 4, 8, 9], we have tried to build invisible interfaces that have little reliance on specialized single-user environments and/or display projection, or custom-designed objects. To this end, we start with everyday objects and embed computation in them in the ubiquitous computing tradition founded at PARC [6, 7]. We have combined four technologies (RFID identifier tags and readers, RF networking, infrared beacons, and portable computing) in a seamless and tightly integrated way. This combination has not been discussed in the literature and is only now being experimented with in research labs working on user interface design.

"CROSSING THE BRIDGE" BETWEEN PHYSICAL AND VIRTUAL WORLDS

We have taken an approach to augment everyday objects that already have some useful purpose independent of any electronic system. The augmentation technology (RFID tags) is sufficiently inexpensive that it can be considered disposable (or in some cases easily recyclable). It is sufficiently small that it does not destroy the integrity or aesthetics of the original object. Although we can certainly build, and have built, custom objects, we mainly use everyday items - which have proved to be the most powerful examples. Our video shows examples of a number of everyday augmented objects: papers, dictionaries, books, business cards, wall posters, printers, and watches. Objects tagged in this way generate new and interesting capabilities whenever an "augmentation-sensitive" device approaches the augmented object. In the video, we demonstrate some possible capabilities using a tablet computer and a wireless network. See [5] for implementation details. (Although the system can operate locally with no network dependencies, in practice we have found that far more interesting scenarios are possible when wireless network connections are incorporated). This enables users to access remote web-based material, digital video sequences (potentially too large to be device-resident), and applications like email.

Lastly, in some scenarios we have used the IrDA ports on the mobile computers to receive a room ID or location information from strategically placed IR beacons. We illustrate this capability using a room-aware IR beacon and a beacon over our stock price fountain. Devices can receive context sensitive information based on location, for example, meeting agendas and dynamically changing stock price quotes.

SOME ADVANTAGES OF RFID TAGS

Notice in the video that the user works in a manner which enables a task focus as opposed to a tool focus. For example, when working on a research paper, he selects various reference materials (to load electronic versions) and dictionaries (to translate articles). The user does not need to think about which applications to invoke, which file pathnames or directories to look in, or which versions are the latest. Similarly, we present a scenario where a user sees a wall poster advertising an upcoming seminar that a colleague recommended. Using the poster title as a reference point, the user can view the on-line abstract to decide if the seminar is a good one to attend. Using the date on the poster, the user can schedule the seminar into an on-line calendar. The tags do not interfere with the original content or form of the physical object. These tags provide:

- **Aesthetics**. These tags are sufficiently small that, with some care, they can be added to most physical objects such that they are invisible at best, unobtrusive at worst

- **Ubiquity and Flexibility.** The technology allows us to extend beyond tagging paper or printed material. This flexibility lets us choose many different locations for tag positioning and supports tagging of highly curved 3D shapes.
- **Cost.** The tags are cheap enough to be considered disposable or, at worst, easily recyclable. There are other tags available that are even less expensive than those we have used (i.e., one cent or less is possible in the future).
- **Robustness.** RFID tags don't degrade over the course of normal usage. They are impervious to dust, dirt, and smearing, and are quite physically robust.
- **Post-Hoc Augmentation**. RFID tags are easily added as a post-process to many physical objects.
- **Sensing Distance or "Reading" Tags.** Because the tag and the reader are loosely coupled during interrogation, the tags do not have to physically contact the sensing device, let alone "dock" in a specific location with a specific orientation.
- **Processing a Tag ID.** Tags are read in tens of milliseconds; unlike barcodes or other optical tags, we are not restricted by image processing software quality and related processing time, camera hardware or image resolution, camera placement, angular skew, or visual obstruction of objects. (In fact, we often take advantage of "visual obstruction" to embed the tags in invisible ways.)

SOME DISADVANTAGES OF TAGS

- **Associating Functionality**. At present we maintain a database in the form of a network-accessible editable ASCII file that associates particular tags with sequences of actions to be taken upon detection of that tag. The administrator of the tag system or the user must register actions and maintain this file. The challenge is to provide easy mechanisms for performing the association of a physically tagged object to a particular set of actions.
- **Knowing what is tagged**. Since barcodes and glyphs both rely on being visible and visually processed, it is clear which objects have these tagging mechanisms. In our scenario, where tags are often invisible, the only way to determine if an object is tagged or untagged, is to try and sense it and have no system response. This could potentially be confused with a system that is simply broken.
- **Location of the Reader**. A tag reader needs to be mounted or attached to the computing device that is to read the tags. This requires some experimentation so as to avoid interference with, for example, the pen sensing electronics while still being convenient and natural for the user.
- **Number of simultaneous tags**. With the RFID technology we are using, we can be read one tag at a time. Therefore tags must be positioned such that there is clear separation to avoid reading ambiguity. Applications should be designed in such a way that objects can be selected sequentially.

SCENARIOS

Using our prototype system, we have implemented a variety of virtual associations for a variety of physical objects. We present a number of scenarios, using a "day in the life of ..." example, as a guide as to how these might be used by an office worker in a workscape of the future.

Our researcher is initially writing a paper. An older version of the paper, tagged with an augmented staple, is used to retrieve the most up-to-date on-line version of the same document. Various reference materials, tagged through staples and bindings, are retrieved electronically using these tags. Finally, one article is translated from French to English using a French dictionary (tagged in the binding) to load and run a translation service on the currently selected document (i.e., context aware). When a meeting reminder interrupts his work, our researcher bookmarks his current context using a physical bookmark. On the way to the meeting, our researcher sees a colleague in the hallway who recommends a current book. Using the tagged book, an order can be placed on-line for a copy. As described earlier, passing posted announcements, our researcher can rapidly obtain more information and enter the talk in his calendar. When the system has been notified that he has arrived in the room, he automatically receives a copy of the agenda for the current meeting. He sends material by email to a colleague using his tagged business card.

CONCLUSIONS

There has long been a discontinuity between the rich interactions with objects in our physical world and impoverished interactions with electronic material. Furthermore, linking these two worlds has been difficult and expensive. In our video, we illustrated our efforts at bridging this physical-virtual gap by subtly augmenting physical objects thereby making them computationally sense-able through combining several technologies in a widely deployable manner. We have shown a number of hopefully thought provoking examples. The research captured in this video reflects our approach and philosophy of creating what we hope will be "invisible interfaces" for the workscape of the future, leveraging the strengths and intuitiveness of the physical world with the advantages and strengths of computation.

REFERENCES

1. Fishkin, K. P., Moran, T., and Harrison, B. L. Embodied User Interfaces: Towards Invisible User Interfaces. *Proceedings of ECHI'98* (in press), Heraklion, Crete.
2. Fitzmaurice, G., Ishii, H., and Buxton, W. A. S. Laying the Foundations for Graspable User Interfaces. *Proceedings of CHI'95*, pp. 422-449.
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. *Proceedings of CHI'98*, pp. 17-24.
4. Ishii, H. and Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits, and Atoms. *Proceedings of CHI'97*, pp. 234-241.
5. Want, R., Fishkin, K. P., Gujar, A., Harrison, B. L. (1998). Bridging Physical and Virtual Worlds with Electronic Tags. To appear in *Proceedings CHI'99*.
6. Want R., Schilit, B. N., Adams, N. I., Gold, R., Petersen, K., Goldberg, D., Ellis, J. R., and Weiser, M. An Overview of the ParcTab Ubiquitous Computing Experiment. *IEEE Personal Communications*, December 1995, pp. 28-43.
7. Weiser, M. The Computer for the 21st Century. *Scientific America*, *265*(3), 1991, pp. 94-104.
8. Wellner, P. Tactile Manipulation on the DigitalDesk. Video in CHI'92 Video Program, *ACM SIGGRAPH Video Review 79*.
9. Wellner, P. Interacting with paper on the Digital Desk, *CACM*, *36*(7), July 1993, pp. 86-96.