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## **Passage: Physical Transportation of Digital Information in Cooperative Buildings**

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**Abstract.** The Passage mechanism introduced in this paper provides an easy and intuitive way to transport various types of digital objects by using also normal physical objects without any special identification tags. The current implementation of the Passage mechanism utilizes electronic scales and contact-free identification devices and thus allows for identification of arbitrary physical objects as well as immediate and unique identification of certain dedicated physical objects. The mechanism is used in various types of cooperative work scenarios in the i-LAND environment (Streitz, et al. 1999) that provides an essential part of the infrastructure for cooperative buildings.

**Keywords.** augmented reality, ubiquitous computing, sensing devices, databases, information spaces, cooperative buildings, roomware

### **1 Introduction**

In order to support people in their communication and cooperation activities, the concept of "Cooperative Buildings" (Streitz et al., 1998) has been proposed. It is characterized by a comprehensive approach on providing information and communication technology throughout the building based on a careful analysis of the tasks and contents, the work practices and organizational structures, and the architectural environment. Initial realizations of parts of this overall approach as, e.g., the i-LAND environment (Streitz et al., 1999), an interactive landscape supporting creative team work, are based on "roomware" components (Streitz et al., 1998) where information technology is integrated in room elements as, e.g., walls, doors, furniture. Examples are the DynaWall, the InteracTable, and the CommChairs (Streitz et al., 1999). Extending the i-LAND approach to the whole building results in spreading roomware components to various parts of the building going beyond offices and meeting rooms to cafeterias, hallways, stairways, foyers, etc.

The devices will be available at multiple places, distributed and embedded in the environment. Thus, computational power and information will be available everywhere (ubiquitous computing, Weiser, 1991). This raises new issues for the design of how people interact with information when using multiple devices. The design has to be aware of the importance of the physical architectural space in which people move around and interact with these devices. Therefore, it is not only designing human-computer interaction but extending the view towards a perspective

that “the world around us is the interface”. Spreading multiple devices in the building allows to create and view information in almost all places in a ubiquitous way. At the same time, there is the demand that people are also able to “carry” this information with them and transfer it between multiple devices in a very intuitive way. In this paper, we will show how we can support these situations of sharing and exchanging information between multiple devices by assigning digital information objects and also processes to arbitrary physical objects taken from the real world.

The paper is organized as follows. In the next chapter, we will describe three sample application scenarios guiding our design. In the third chapter, we present the *Passage-Mechanism* as our proposal for a solution of the problem introduced above. In the fourth and fifth chapter, we explain how we identify physical objects, which act as *passengers*, in various ways and assign digital information to them via so called *bridges*. This is followed by a description of how data and applications interact with passengers. Finally, we present related work and discuss future plans.

## 2 Sample Application Scenarios

We now describe sample application scenarios resulting from the availability of multiple information devices in the environment of Cooperative Buildings.

### Agenda Planning and Meeting Preparation

Imagine a person who is preparing the agenda of a meeting, sitting at a desktop computer in his office. He creates the agenda and links various background material (documents, presentation slides, pictures, video clips, etc. ) to the different items of the agenda. He has to store the agenda as a file, name the file, select a directory in his or in the team’s directory structure on the server and place it there. Later, at the time of the meeting, he walks over to the meeting room. There, he wants to display the agenda and the background material for the meeting on an interactive, electronic wall (e.g., the DynaWall in the i-LAND environment) or by using an LCD projector connected to a networked computer in the meeting room. In order to get access to the agenda file stored on the server, he has to identify himself and log in to the server, navigate to the directory, find and select the file, open and display it. Hopefully, he has appropriate access rights, remembers the directory and file name, etc. Thus, a number of steps, error prone steps, are involved. In the "traditional" case of using paper for the agenda, he writes down the agenda items on a piece of paper, copies it, takes the physical objects “paper sheets” and carries them to the meeting room. We come back to these physical actions.

### Capturing Information from Discussions

Another scenario is where two (or more) people meet in the hallway or the cafeteria and start an informal conversation. This informal conversation evolves into a non-planned discussion of some project issues. They start to illustrate their discussion by drawing a sketch on a whiteboard in the hallway or on a piece of paper on the

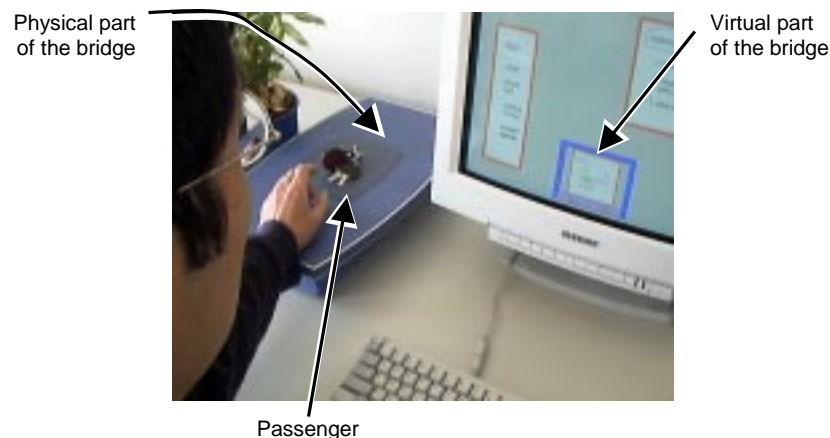
bistro table. Afterwards, the people want to use the results of their discussions in their offices or in an official, scheduled meeting. In case of the physical whiteboard, this will be difficult. One has to copy this information somehow. In the case of the piece of paper, one can take it but it is not electronically available unless it is scanned and filed, etc. In case they are in a cooperative building, the whiteboard will be an interactive wall (DynaWall) and the bistro table in the cafeteria an interactive table (InteracTable). Sketches drawn on these roomware components can be easily stored as electronic documents. If they want to use this information in a different place, they have to go through similar processes as in the example before. Wouldn't it be nice to take and carry the electronic document around similar to a physical object ?

### Starting Applications

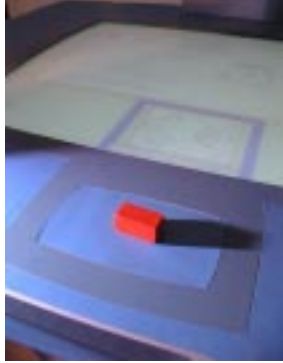
A third case is the example of starting an application on one device, e.g., the presentation program on an interactive wall, on a computer connected to an LCD projector in a meeting room or a cooperative group application on several devices. Again, it is an awkward and cumbersome process finding the programs, starting one after the other, etc. Wouldn't it be nice to have a "magic" object, place it somewhere and everything is being started without overhead ?

## 3 The Passage Mechanism

While we have described some application scenarios leading to the design of the Passage mechanism in the context of a cooperative building, the problem and our approach to provide a solution is not limited to that application context. The problem of transporting complex information structures created or collected at and from various sources exists and has to be addressed in almost any environment with similar characteristics. Common to all of these situations are a number of awkward tasks: numerous tools have to be started, the material has to be arranged, maybe copied, and



**Fig. 1:** Assigning information to a key chain as an example of an arbitrary physical object



**Fig. 2:** Passenger on a bridge

finally sent to the new location, e.g., by e-mail attachments, ftp or similar services. When the person who sends this information arrives at the new location, a similar activity of finding and unpacking the material begins.

In order to facilitate this process, we developed a concept called *Passage*. Passage describes an elegant mechanism of connecting information structures in the digital, virtual world of computers with a real-world object. This object, which we call a *Passenger*, can be seen as a physical bookmark into the virtual world. One can connect information to a passenger and physically transport it to a new location. Then, by simply putting it on a special device called a *bridge*, the connected information is immediately fetched from a database

and displayed on that screen which corresponds to the bridge. It is no longer necessary to open windows, browse hierarchies of folders, worry about mounted drives and doing similar annoying actions.

A *passenger* does not have to be a special physical object. Any uniquely identifiable physical object may become a passenger: a key chain, a watch, a ring, a pen, a wooden block, or many other kinds of objects. You can take whatever you happen to have around at this moment. The only restriction passengers have is that they must be detected by a bridge and uniquely identified by the system. Fig. 1 shows the process for the first scenario, i.e. a person sitting at his desktop computer and using a key chain as a *passenger* by placing it on a *bridge* where sensing devices are embedded. The bridge has a physical part (left side of the picture) where you place the passenger and a virtual part, a window appearing on the screen (see the rectangle on the lower part of the screen). The assignment is done by a gesture, simply by dragging the electronic object on the screen onto the rectangle representing the virtual part of the bridge. Note that the digital information is not stored on the physical passenger object. The passenger functions only as a physical representative. While Fig. 1 shows a stand alone mobile bridge, Fig. 2 shows a bridge integrated in the InteracTable and a wooden block as another example for a passenger. Fig. 3 shows the retrieval and display of information after placing a passenger on a bridge.



**Fig. 3:** Displaying information

## 4 Detection and Identification of Physical Objects

Detection and identification of physical objects play essential roles in the Passage mechanism. The current implementation of the Passage mechanism realizes two different methods to detect and identify objects; one uses the weight of physical objects and the other uses electronic ID tags. When using the weight anything that can be measured by scales can be used as a passenger. When using electronic ID tags, we can take advantage of their capability that allows for immediate, unique and highly reliable detection and identification.

### 4.1 Identifying Objects by Weight

The bridges we built are equipped with electronic scales in order to measure the precise weight of physical objects and send it to computers. Here, the weight is used as an ID for the electronic document/ the digital object. Since the electronic scales are sensitive enough to detect the difference of 0.1 g, they even respond to slight changes of surroundings including air flow and occasional vibrations of the floor. Such environmental disturbances are detected and filtered out by the device manager software. Also, it takes a few seconds for the scales to obtain the precise weight, which could be problematic when users require immediate access to information. In order to solve this problem, the device manager has a heuristic function that reduces the time required to measure the weight of *passengers*. It computes the weight before the value of the scale actually converges in a few seconds while the virtual part of the bridge is launched on the display (see Fig. 1 ).

### 4.2 Identifying Objects with Electronic ID Tags

The bridges are also equipped with contact-free identification devices (MIKRON's EasyKey™) in order to read electronic ID tags (see Fig. 4). The bridges obtain 32-bit identifiers from ID tags when the distance between the bridges and the ID tags is less than 6 – 10 cm, depending on the type of the tags. It is not necessary to insert them in certain dedicated slots but only to place them on top or to hold them close.



Fig. 4: Identification device

In addition, the ID tags can be pasted on or embedded in normal physical objects. The process to detect and identify ID tags is performed much more quickly than the weight. A small ID chip and an induction coil within an ID tag initially receives electric power and a trigger code from a bridge. A few hundred milliseconds after this initial action, the *bridge* receives a 32-bit identifier from the ID tag. The identification devices together with the scales allow for reasonably quick identification of arbitrary objects as well as immediate and unique identification of tagged objects.

## 5 Connecting Physical Objects and Digital Information

Fig. 5 shows various components of the Passage mechanism. Physical objects and digital information objects are associated by the Passage agents that manipulate the data in the Passage databases and the device managers. Most of the major components in Fig. 5 can communicate with one another over the network so that they can be distributed across rooms and buildings. Thus, the Passage mechanism can be easily configured for different types of cooperative buildings.

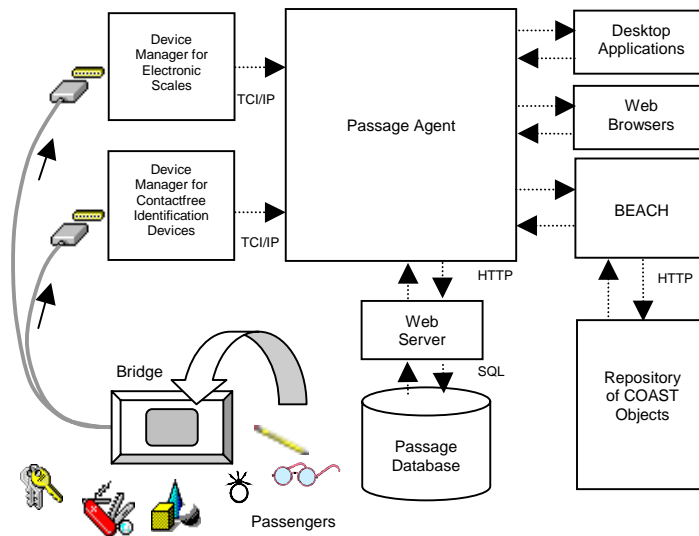


Fig. 5: The Passage mechanism

### 5.1 Passage Agents

The Passage agents link physical objects and digital information by using the data received from the device managers and the Passage databases. As soon as a passenger is put on a bridge, electronic signals from the bridge are handled by appropriate device managers according to the types of the devices that are activated by the passenger. The Passage agents obtain the physical properties of the passenger such as the weight and/or the identifier. When the passenger is new to the agents, they associate the passenger with the digital information specified by the user and store the relationship as a record in the Passage databases. When the agents know the passenger already, they simply retrieve a record from the databases and automatically display the digital information corresponding to the passenger. There is no need to manually launch applications or select menu items. The only thing users have to do is to put a passenger on a bridge and wait for the information to be presented on the screen.

## 5.2 Passage Databases

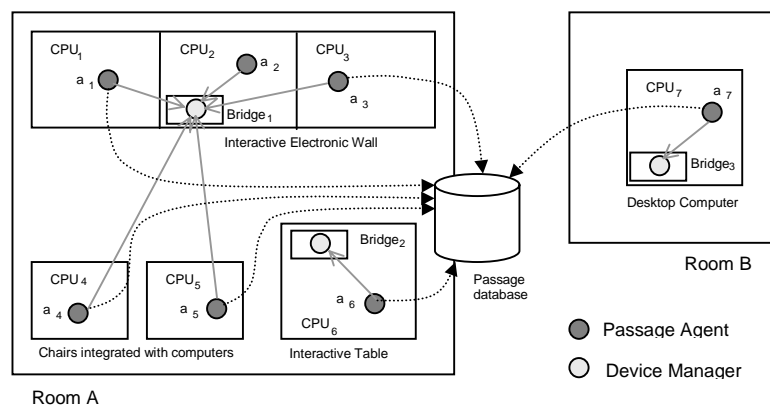
The current implementation of the Passage mechanism utilizes a simple relational database management system that can be accessed via the HTTP protocol. Therefore, Passage agents distributed on the network can easily access the Passage database and manipulate the attributes of passengers including:

- weight
- electronic ID
- information object (or pointer to information object)
- type of information object
- timestamp

## 5.3 Configuring Passage Agents

Passage agents and device managers communicate with each other using TCP/IP sockets. The use of TCP/IP sockets permits to flexibly distribute the Passage agents and the device managers in rooms and buildings, which is a part of the first step towards the ubiquitous collaboration environments.

Fig. 6 shows a sample configuration of passage agents and device managers for selected roomware components as, e.g., in i-LAND. There are six Passage agents  $a_1, a_2, \dots, a_6$  in Room A, five of which are connected to the device manager of  $\text{Bridge}_1$ . Under this configuration, a passenger placed on  $\text{Bridge}_1$  invokes actions on the three computers ( $\text{CPU}_1, \text{CPU}_2, \text{CPU}_3$ ) behind the interactive electronic wall and the two computers ( $\text{CPU}_4, \text{CPU}_5$ ) integrated with chairs. In contrast, a passenger on  $\text{Bridge}_2$  or  $\text{Bridge}_3$  invokes actions on only one computer ( $\text{CPU}_6$  or  $\text{CPU}_7$ , respectively). All Passage agents access the same Passage database so that digital information can be transported across  $\text{Bridge}_1, \text{Bridge}_2$  (in Room A) and  $\text{Bridge}_3$  (in Room B).



**Fig. 6 :** Sample configuration of Passage agents

## 6 Interacting with Data and Applications via Passengers

Passengers can be used to interact with various types of data and applications. As shown in Fig. 5, Passage agents can control general applications, web browsers and BEACH (Basic Environment for Active Collaboration with Hypermedia), which is the software infrastructure for roomware environments, developed to meet the requirements of i-LAND (Streitz et al., 1999).

### 6.1 Interacting with BEACH

BEACH runs on roomware components such as the *DynaWall* (an interactive electronic wall), the *InteracTable* (an interactive table) and the *CommChairs* (computer enhanced chairs) and provides shared hypermedia functionality, gesture-based interaction methods, and many other functions for collaborative work. Users of the BEACH software can utilize passengers to transport information such as a meeting agenda and results of brain storming sessions across different roomware components which might be placed in different rooms. The only requirements are that they are connected to the network and that they have a bridge. When users put a passenger on a bridge, a small window appears on the screen, sliding up from the physical location of the bridge. Objects can be dragged out of BEACH applications and dropped on the window in order to assign them to the passenger. The objects assigned to the passenger are inserted into a repository and a database. When the passenger is put on another bridge, the objects are retrieved from the database and the repository and displayed in a small window of the display corresponding to this bridge. Then, the objects can be dragged out of the window and dropped on the BEACH applications.

### 6.2 Interacting with the Web and General Desktop Applications

Passengers can also be used to store and display URLs. Since various MIME types are handled by web browsers, this feature augments the Passage mechanism with a simple facility to manipulate applications and multimedia data types.

In addition, passage agents can directly control regular desktop applications to start and stop word processors, spread sheets, presentation software, etc. The applications and the files that are connected with passengers do not have to be on shared file systems. When they reside on local file systems, they are transferred via the HTTP protocol using the POST method.

## 7 Related Work

We presented the concept and implementation of the Passage mechanism, a novel transport mechanism of information. Our approach is related to and was inspired by certain developments in human-computer interaction, augmented reality, ubiquitous computing and computer-supported cooperative work.

Comparing the Passage mechanism with related work shows that the general idea of using physical objects to move information from place to place is not very new. For example, floppy disks are used to copy and move information around. However, since their storage capacity is severely limited, one often has to go through a complex process to send information by email, ftp, etc.

Informative Things (Barrett and Magilo, 1998) proposes a method to attach network information sources to floppy disks so that they can hold virtually unlimited amounts of information. However, floppy disks, all of which have very similar physical characteristics, have to be inserted into special disk drives and ejected from them.

A related but different approach is the notion of “graspable“ user interfaces (Fitzmaurice et al., 1995) and “tangible bits“ (Ishii and Ullmer, 1997) which was also inspired by the “marble answering machine“ developed by Bishop (Poynor, 1995) where incoming phone calls are indicated by (physical) marbles which can be placed on a specific area for playing the message. MediaBlocks (Ullmer et al., 1998) uses wooden blocks that physically contain ID tags and serve as containers, transports, and controls for online video data (or other media streams). Our Passage approach is not media transport, browsing, and editing but attempts to realize ephemeral binding between physical objects and digital contents considering requirements of cooperative work. Therefore, we made it possible to use arbitrary objects as physical representatives of digital information. Furthermore, our Passage mechanism can easily be configured to support work in cooperative buildings. It provides an intuitive way for transporting information across computers, offices, meeting rooms, etc. as described in the application scenarios in Chapter 2.

## 8 Discussion and Future Work

The first implementation of the Passage mechanism described in this paper convinced us that our approach to use physical objects for representing and transporting digital objects is promising. We utilize two different methods to identify physical objects; identification by weight and identification by electronic ID tags. The use of weight makes the mechanism work without special ID tags. This generally works well when the stored information is immediately transported and retrieved (=> short term memory), e.g., in group work situations. In contrast, passengers with electronic ID tags are always uniquely identified. This requires that ID tags have to be pasted on or embedded in physical objects (=> long term memory).

When passengers are not transported and used immediately, users would need to remember which passenger is connected to which information object. In the future, we will explore the possibilities of storing and/or displaying information on passengers themselves. Small electronic devices including cellular phones, PDAs and palmtop computers will be used as "active" passengers which can send, receive, store, process, and/or display information. The use of such gizmos in the Passage mechanism would support certain types of mobility in various activities in cooperative buildings.

While using the first implementation of the Passage mechanism in our i-LAND environment, we found that the capability of Passage agents to simultaneously start up and quit applications on multiple computers was extremely useful. We are interested

in extending this capability besides the primary function of the Passage mechanism as a physical transportation medium.

For future developments, it is essential to design a generic Passage framework, which we call *Open Passage*, in order to provide generic APIs for varieties of devices and data types. In addition, security issues have to be investigated in order to develop a security model for the Passage mechanism.

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### References

1. Barrett, R. and Maglio, P. P. (1998). Informative things: how to attach information to the real world. In: *Proceedings of UIST '98* (San Francisco, CA, Nov. 1-4). ACM Press, New York, 81-88.
2. Fitzmaurice, G., Ishii, H., and Buxton, W. (1995). Bricks: Laying the foundations for graspable user interfaces. In: *Proceedings of CHI'95*, Denver, CO, (May 7-11). ACM Press, New York, 442-449.
3. Ishii, H. and Ullmer, B. (1997). Tangible bits: Towards seamless interfaces between people, bits and atoms. In: *Proceedings CHI '97*, Atlanta, Georgia, (March 22-27, 1997). ACM Press, New York, 234-241.
4. Poynor, R. (1995). The hand that rocks the cradle. *I.D. - The International Design Magazine*. May-June.
5. Streitz, N. A., Geißler, J. Holmer, T. (1998) Roomware for Cooperative Buildings: Integrated Design of Architectural Spaces and Information Spaces. In: [7], 4-21.
6. Streitz, N. A., Geißler, J. Holmer, T. Konomi, S., Müller-Tomfelde, C., Reischl, W., Rexroth, P., Seitz, P., Steinmetz, R. (1999). i-LAND: An interactive Landscape for Creativity and Innovation. In: *Proceedings of CHI'99*, Pittsburgh, U.S.A. (May 15-20, 1999). ACM Press, New York, 120-127.
7. Streitz, N., Konomi, S., Burkhardt, H. (Eds.) (1998), *Cooperative Buildings — Integrating Information, Organization and Architecture. Proceedings of the First International Workshop on Cooperative Buildings (CoBuild'98)*, Darmstadt, Germany, February 1998. Lecture Notes in Computer Science 1370. Springer: Heidelberg, 4-21.
8. Ullmer, B., Ishii, H., and Glas, D. (1998). mediaBlocks: Physical containers, transports, and controls for online media. In: *Proceedings of SIGGRAPH '98* (Orlando, FL, July 19-24). ACM Press, New York, 379-386.
9. Weiser, M. (1991). The Computer for the 21st Century. *Scientific American*, 1991, 265 (3), 94-104.