Natural Storage in Human Body

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Abstract. We propose using the human body for "storing" data used in devices for the imminent ubiquitous computing era. In the future, people will use information appliances as powerful creativity tools, using them for taking pictures, recording ideas, and recording voices. Removable medium are now widely used with such devices to record the data. However, data stored on a physical medium is troublesome to handle and thus hinders smooth knowledge creation. Natural storage using the human body would eliminate the physical burden.

1 Introduction

Storage devices that enable the user to store and carry digital data have played an important role in computing. Today, both removable media (e.g. compact disks, memory cards, and floppy disks) and fixed media embedded in a device (e.g. hard disks) are widely used.

In the upcoming era of ubiquitous computing, people will live in an environment where information appliances[1], i.e. tools in which computers are embedded, are distributed. Appliances that produce and/or replay digital data, such as digital cameras and portable voice recorders, will be particularly useful for organizing ideas. These appliances, however, will still require storage capability.

While removable media are fairly convenient for storing digital content, their weight and bulk impose a physical burden. In addition, breakage or theft of the media results in loss of data. While there has been research into storage for use in the ubiquitous environment, the systems proposed so far use physical (i.e. visible) media. They thus have the same problems inherent to conventional removable media. For example, the tangible file systemm[2] connects the ID on a sheet of paper to digital data. The personal server[3] is a mobile device that enables the user to carry personal storage in a ubiquitous environment.

We propose using the human body as a "storage device" by creating an illusion of data being stored in the body. We call this concept **natural storage**. Natural storage eliminates the problems of size, weight, etc. of conventional removable medium. Actualizing this concept requires developing appliances that give the user the illusion that data is stored in the user's body. We developed prototypes of two such appliances to demonstrate this concept.

2 Concept of Natural Storage

The fundamental concept of natural storage is using the human body for storing digital data. Natural storage is used with appliances that need access to data in everyday life. It requires less knowledge of computers or data storage concepts as compared with current removable media. Natural storage does not require complicated knowledge, such as the path of files, the size of files, and the capacity limit of storage.

An example scenario of using natural storage is as follows. Today, we enjoy watching images taken with digital still cameras. To watch the images, we first insert a memory card into a camera to record the image data, and then we display the images on a computer screen or print them out to paper. When natural storage is applied to this situation, the images generated by the digital camera appear to be stored in the user's body. And when an appliance for outputting the data, such as a printer or a display, the data is directly output from the body(Figure 1).

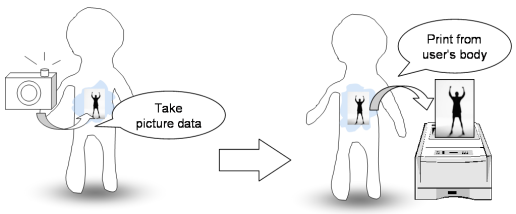

Fig. 1. Use of natural storage with appliances, capturing and printing out still images

It is also possible to apply natural storage to an appliance like a microphone for recording voice. When a user holds the microphone and speaks, the sound is recorded into the user's body. Then, using an appliance like a headphone, the user can listen to the stored sounds.

These appliances could be widely distributed for public use, enabling people to record or retrieve ideas. As people carry a pen and paper for recording and organizing their ideas today, these appliances will support creativity in the ubiquitous environment.

Using the human body for storage has three advantages in particular.

1. Carrying data imposes no burden because natural storage has neither weight nor size.
2. Data cannot be lost due to physical breakage.
3. The media cannot be forgotten. Since the data is stored in the user's body, the person always has it.

The first two still hold even in comparison to storing data in small and/or wearable devices such as cellular phones. As long as physical objects external to

the user's body are used as media, there is still a burden. Even if the media is fully miniaturized, there is still the risk of the media being lost.

3 Design of Appliances

The key to the natural storage concept is giving the user the illusion of storage being in the user's body. This is done by implementing two functions in the appliance. (1) The appliance detects the user's ID and associates it with the user's actual storage in a network. (2) The appliance gives the user feedback as if natural storage is in the user's body.

To enable data to be carried and stored like data on removable media, the appliance associates the user's ID with actual storage in a network. Since networking is available anywhere in a ubiquitous environment, the storage associated with a user can be accessed anywhere. The implementation of storage in this way means that the access authority is attached while restrictions on the storage capacity can be concealed. The information needed for association is stored to a database. When the appliance is activated, the appliance sends the user's ID to the database and requests the location of the actual storage.

To create the illusion that the user's body is a storage device, the appliance gives the user feedback as if the data were actually being stored in and retrieved from his or her body as the user uses the appliance. Considering the interactions between a user and a storage device will help clarify the interfaces between the appliance and user. When storage is used, there are two interactions:

ADDRESSING. Addressing specifies the storage to be used. This corresponds, for example, to the insertion of a floppy disk or the specification of a URL.

FEEDBACK. Feedback presents the user the existance of storage. Feedback includes, for example, the blink of a pilot lamp and the sound and vibration of a spinning disk.

Note that a user cannot actually see what is happening between an appliance and the actual storage. The user grasps the image of storage using only the information acquired from interactions with the appliance. Therefore, the interface of an appliance should have two interactions, addressing and feedback, that give the user the illusion of data storage. Figure 2 illustrates how the user images natural storage. An appliance identifies the ID of the user(1), accesses the user's actual storage(2), and returns the result to the user(4). The addressing interaction corresponds to detecting the user's ID. The feedback interaction corresponds to presenting the result. Both of interactions, (1) and (4), cause the user to image the natural storaege(3). The designs of each interaction are as follows:

- For ID identification, the appliance should support biometric identification methods, such as fingerprint and iris pattern recognition, because such methods actively involve the human body. The best method to use depends on the

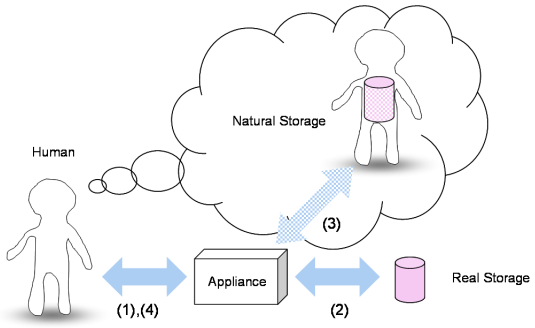

Fig. 2. The user images natural storage, not a real storage, from the interaction with the appliance.

type of appliance. For example, fingerprint recognition is effective for handheld appliances, such as microphones and digital cameras. Camera-based ID verification is suitable for appliances used at a distant.

– The interface supporting feedback interaction should also use the user's body. For example, an access lamp attached on the user's body can help create an illusion of storage. The illusion is enhanced by providing virtual sounds and vibration associated with using natural storage.

4 Prototypes

We are developing two appliances that use natural storage.

4.1 Natural Storage Camera

Our natural storage camera (NS camera) is a digital camera that uses natural storage. A fingerprint sensor functions as the shutter button. The data for pictures taken with the camera are virtually stored in the body of the person who presses the shutter button (Figure 3). Consequently, the camera does not need removable media to record picture data.

We are using NTT Docomos F900iT cellular phone for the prototyping. The F900iT has a camera, fingerprint sensor, and wireless internet connection. These functions are controlled by a program written in Java. Moreover, its size and portability are similar to those of a typical digital camera. Figure 4 shows an overview of the prototype.

The functions are as follows. When the user slides his or her finger on the fingerprint sensor, the camera takes a picture. Simultaneously, the camera obtains the user's ID from the fingerprint and acquires the network path to the actual storage from a database on the server. The picture data is then uploaded to the actual storage associated with the ID. From the user's viewpoint, it appears as if the data was saved inside his or her body through the finger.

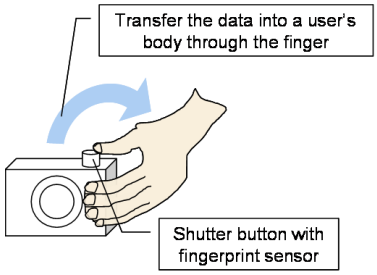

Fig. 3. NS camera overview

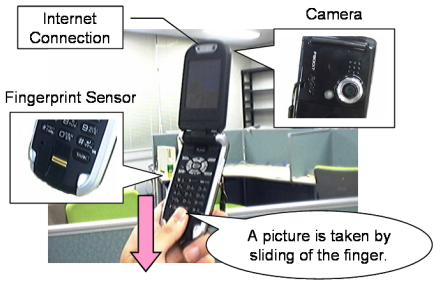

Fig. 4. Prototype of NS camera (F900iT)

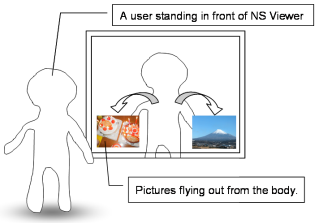

Fig. 5. NS viewer overview

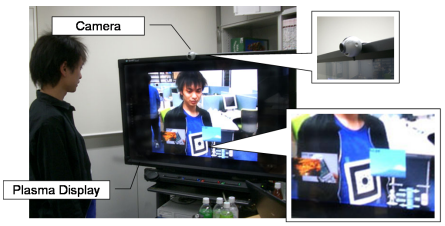

Fig. 6. Prototype of NS viewer

4.2 Natural Storage Viewer

Our natural storage viewer (NS viewer) appliance is a kind of mirror for looking at pictures stored in a user's body. Figure 5 shows an idealized image of the NS viewer. It consists of a display and a camera. When the user stands in front of NS viewer, not only is the user's body mirrored but so are the pictures stored in the body. The pictures appear to fly out of the body and then circle along the user's image in the screen. The scale of the pictures changes with the distance between the viewer and the user. To look at the pictures more closely, the user approaches the viewer.

Figure 6 shows a picture of the NS viewer prototype. It consists of a plasma display and a 110,000-pixel resolution camera. The camera is attached to the upper part of the plasma display so that the scene in the front of the camera can be captured. In the present version, a square marker is attached to the user to enable the user's ID to be detected and to determine the user's location.

NS viewer works as follows. First, one frame in the video stream from the camera is captured, and the ID of the marker and its position in the frame are detected using the ARToolKit[4]. Next, the location of the storage associated with the ID is obtained from the database. In the present version, the location of the storage is represented by a URL. Picture files are downloaded from the directory to the location designated by the URL and superimposed around the marker in the frame. The plasma display then shows the resulting image. The image is flipped horizontally like in an actual mirror.

From the user's viewpoint, the operations inside the system, which were described above, are not visible. The interaction between the viewer and the natural storage appears simple. Standing in front of the plasma display corresponds to the addressing interaction. The pictures circling the body, as reflected on the screen, correspond to the feedback interaction. Together, the addressing and feedback interactions give the user the illusion of the storage being in the user's body.

5 Discussion and Future Work

There are several approaches to making natural storage practical.

One possible approach is to embed in the user a memory device that can wirelessly access by radio. While embedding RFID tags in the body is already practical[5], it still carries a physical risk and can create mental anxiety. Our approach of associating storage with a personal ID results in virtual realization, so there is no risk or anxiety.

Storing data and carrying data between appliances can be done using network sharable storage (e.g. NFS on Linux), which does not require a removable storage device. There is thus no physical burden, similar to natural storage. However, from the user's viewpoint, storage on the network is a logical concept with no shape. Natural storage uses a concrete object, the human body, as imaginary storage.

Theoretically, many types of data could be stored using natural storage. How to handle a large amount of data in natural storage, i.e. scalability, is a major issue. As the amount of data increases, the need for managing the data also increases. Conventional removable storage devices and file systems use physical media, enabling the user to understand the location of the data intuitively. To enable the user to intuitively recognize data stored in natural storage, we could store the different types of data in different body parts. For example, text data could be stored in the left hand, pictures in the right hand, and music in the ears. With an appliance like NS viewer, the user could recognize the different types visually.

An appliance that accesses natural storage needs to be in an environment in which there is a radio network. Candidate locations include spaces where a computer is omnipresent, such as Active space[6]. A limited space, like a classroom or office, may also be suitable.

We plan to enhance our prototypes. For example, the present prototype of NS viewer recognizes a user's ID by detecting a marker attached to the user's body. Personal recognition using image processing would be more efficient.

6 Related Work

Some systems assign IDs to objects and associate online data with those IDs. mediaBlocks [7] uses a wooden block attached to an RFID tag, called a "tangible

bit", as a container for online data. IconSticker[8] transfers an icon on a computer desktop to the real world as a paper icon printed as a barcode. This enables treating data as real-world objects. Pick and Drop[9] moves data between a computer and real-world objects by using the barcode. The prototype enables data to be transferred from paper to a computer, apparently with a pen-type device. All of these systems involve real-world objects or an exclusive-use device. Consequently, they impose the same physical burden as removable media. In contrast, natural storage, which appears to use the human body for storage, imposes no such burdens.

7 Conclusion

In this paper, we proposed natural storage that seemingly exists in the human body. It eliminates the physical burden of conventional removable storage. For it's application, natural storage enable people to record ideas anywhere at anytime with information appliances. The appliance interface should have two interactions, addressing and feedback, that give the user the illusion of data storage and retrieval. Two prototypes, a natural storage camera and a natural storage viewer, have demonstrated this concept.

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