Digital Decor: Augmented Everyday Things

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Abstract

Digital Decor is furniture, appliances, and other small objects commonly found in homes and offices that have been augmented with computational power to extend usefulness. As such, Digital Decor is a physical manifestation of the ubiquitous, pervasive, and invisible computer in which the familiar, everyday object is imbued with additional capabilities through a single, simple application. Thus far we have investigated two possible functionalities for Digital Decor: everyday objects that keep track of their own contents (this can be called "smart storage"), and everyday objects that support informal, lightweight communication. For this paper we developed four prototypes: Timestamp Drawers and Strata Drawer are Digital Decor prototypes augmented to keep track of their contents while Peek-A-Drawer and Meeting Pot are prototypes augmented to support communication.

Key words: Ubiquitous computing, smart furniture, lightweight communication, aroma display, drawers, appliances, Digital Decor.

1 Introduction

In the near future, we will be using many single purpose information appliances equipped with ubiquitous, invisible computers [11]. Decor such as furniture, appliances, and other small objects commonly found in homes are a good place to install invisible computers, because they also have single or, at most, a small number of functions, and have familiar, simple operations.

We can design decor enhanced with invisible computation, or "Digital Decor", drawing on the user's knowledge of original decor's function and operation, just like we have been designing GUIs using real-world knowledge as metaphor. The challenge of designing Digital Decor is in the design of the interface between the activities of everyday life with the decor and the invisible digital world.

Although there are many possibilities for Digital Decor (for examples [10][5][9]), we have focused on two application areas: Digital Decor as smart storage and Digital Decor for lightweight communication. We developed four Digital Decor prototypes: Timestamp Drawers and Strata Drawer which are smart storage prototypes and Peek-A-Drawer and Meeting Pot which are prototypes that support lightweight communication. While they appear to be ordinary everyday objects like a chest of drawers or a coffee pot, they are augmented with inconspicuous computers that extend their capabilities in interesting and useful ways.

2 Digital Decor Applications

2.1 Smart Storage

Many people prefer to organize soft copy documents in desktop computers rather than to manage hard copies in conventional file cabinets, because of the many advantages computers can provide. Documents in a computer can be easily edited, effectively used, and shared. Another reason to put documents in a computer is that the computer can help find a digital document by searching for text in the title and the contents, or by sorting the associated timestamps that are created and modified. Capabilities to find physical items in the real-world can also be realized by augmenting everyday storage decor such as drawers, cabinets, shelves, toy boxes, shoeboxes, and letterboxes with embedded computation designed to assist in location of the stored items they contain. These ubiquitous computers embedded in decor can support the search for items by keeping track of all the items placed in the decor and all the salient interaction events associated with those items. Examples of this include sensor augmentation that provides a timestamp log of access, voice-recognized text annotations, identification tags like barcodes that are associated with the items, and pictures taken automatically by the decor. These pieces of everyday decor, with their embedded, ubiquitous computation, are forms of what we have come to call Digital Decor.

2.2 Lightweight Communication

Computers have variegated communication between people over distance allowing modes of communication that range from incorporated virtual reality devices, to innovative communication such as the tangible tactile display [1]. We have investigated how embedded ubiquitous computers might provide a new role as a tangible and

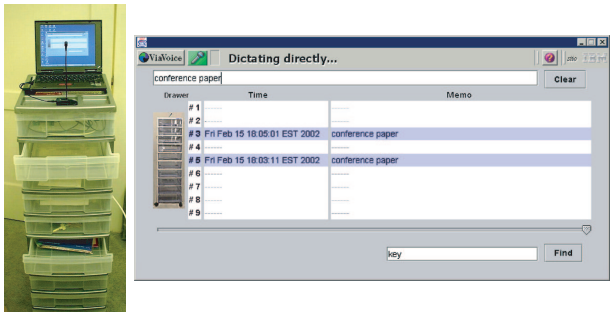

Figure 1: The Timestamp Drawers (left) and a close-up of the display (right).

ambient communication tool for everyday things. Rather than augmenting traditional organizer functions, such as assisting in the location of stored items in a chest of drawers, we might make them a new communication device that will be used to connect distant family members or co-workers. Everyday objects that support informal, lightweight communication form the second area of application that we have explored for Digital Decor. Embedded sensors and computers can transmit salient aspects of a person's everyday use of certain objects to someone in a distant location and in so doing foster a sense of connectedness between them. For example, a picture of the objects inside a child's toy box, if transmitted into the grandparent's home, could foster further communication between a grandparent and a grandchild. Further, by co-opting an object's original, tangible operations (for example: open the lid and place an object in the toy box) to also cause a picture of the contents to be sent to the remote location, we can make a communication device that is as simple to use as the original.

3 Timestamp Drawers

3.1 Finding Items by Timestamp

It is not unusual to find yourself asking: "Where is the document I received at that meeting?" Although it may be difficult to remember exactly where we have stored a particular document, you may easily remember that the document was distributed at a particular meeting. Further, the time of particular events (like the aforementioned meeting) can be determined from the daily schedule found in a person's public calendar. With this information, the previous question can be converted to: "Where is the document I received Tuesday afternoon?" Storage furniture like shelves and drawers that record timestamps of human access to its compartments can then be used to direct the user where to look.

Figure 1 shows the Timestamp Drawers, one of the Digital Decor prototypes. This cabinet is 107cm high $\times$ 32cm wide $\times$ 40cm deep and has 10 drawers, each with an open/close sensor created from a reed switch and magnet combination. Open/close events of drawers are logged and time-stamped by the computer located on top of the drawers. These drawer events are logged and displayed as shown on the right in Fig. 1, where each line indicates a drawer with its timestamp. Additionally a user can add text annotations to the log of opened drawers, using either the keyboard or voice recognition (IBM ViaVoice).

A user can browse the Timestamp Drawer's log to find the drawer which likely has the desired item either by moving the time slider looking for an event that coincides with the meeting in question, or by searching for keywords in the annotations. Once the usefulness of logging the drawer events is confirmed, we will re-design the browser to make it pervasively replacing the keyboard and display with, for example, a tangible calendar, voice input, and embedded indicators on each drawer.

3.2 Discussion

In the past, the owner of a non-augmented version of a cabinet like that seen in Fig. 1 would label each drawer, and organize items by putting them in the drawer with the appropriate label. Grouping, however, is always a difficult problem and it often happens that there is more than one labeled drawer that would be appropriate for a particular item to be put in. Further, even if the appropriate grouping is unique, some drawers may overflow because their fixed capacity is not sufficient to store all the items of a particularly large group. To avoid the possible overflow caused by a particularly large group, drawers require some empty space, but too much unused space is inefficient.

Timestamp Drawers solves the fixed capacity drawer problem through the addition of a computer-assisted logging and search function making it a more flexible, efficient storage medium. It is similar to a computer file system in which hard disk sectors of fixed size are abstracted to support files of flexible size and number. Our drawers allow users to just put items in any available drawer, without labeling the drawers and, since the drawers are not labeled, without either having to decide which category is appropriate for the item or searching for the appropriately labeled drawer.

4 Strata Drawer

4.1 Camera for Storage

Where Timestamp Drawers has a single bit, open/close sensor for each drawer which it uses to attach context in the form of a timestamp for each open/close event, we could use that single bit to provide a different, possibly more useful, kind of context access cue.

Although taking pictures of cabinet or closet contents is sometimes recommended as the secret of storage mastery, the overhead involved in finding the camera, taking the picture and then storing those pictures in a way that makes them ready for use as a reference is prohibitive.

If storage furniture were equipped with a sensor, a camera and an embedded computer to both control the camera and act as picture server, finding objects in the storage could be made much easier. For example, a cupboard equipped with a camera inside the door, or a toy box with a camera under the lid can take a picture of its contents when a user closes the door. By browsing these pictures in time sequence, a user could find items even if they are obstructed by objects more recently placed in front (or above) them. If the images captured by the camera are automatically served to the web, the user will be able to remotely view the contents of two or more of these Digital Decor and never have to move room to room, or house to office in search of items.

4.2 Finding Items in a Stack

Many office workers have stacks of documents on their desk. In well organized offices, these documents will soon be grouped and stored in file cabinets, drawers, or trash cans. This grouping, for a variety of reasons, tends to be a difficult problem except, perhaps, for a long established, highly structured business. In addition to the problems with grouping we always seem to have certain documents that could be discarded but may be required someday, so we keep them on our desk. As a result, document stacks never disappear from our desktops.

To find a document in an unordered stack is a difficult job. One approach to this problem is to use a geological cue in the strata of the documents. Since one way that document stacks grow on the desk is in time sequence; we know that we can find older documents in the lower strata. If, in the process of searching for a particular document, we find a related or contemporary document, we can guess the target document is in the nearby strata.

While putting all the stacks of documents in a box or a drawer would make the working area on the desktop larger, it would make finding items in the stack difficult. We can design Digital Decor for the storage of such a document stack that provides strata information on the contents.

4.3 Prototype

Strata Drawer, seen in Fig. 2 is our prototype of a camera-enhanced cabinet used for storage. This cabinet has a single, deep drawer equipped with a camera, a height-sensor and a computer. When a user places an object in the drawer and closes it, a photograph is automatically taken, and the height of the contents is measured by a laser beam. A user can browse pictures of strata in the drawer's contents, with timestamps and height information.

Figure 2: The Strata Drawer has a digital camera (upper center) and a laser diode (upper right) that is used to measure the height of the contents.

Made from a commercially available three-drawer chest, the Strata Drawer measures 64cm high $\times$ 49cm wide $\times$ 39cm deep. We have removed the top drawer, and combined other two drawers to make one deep drawer. In place of the original top drawer we have equipped the cabinet with a reed switch, halogen lamps, a digital camera (Olympus D-360L), a laser diode, and electronic circuits. These devices are connected to the computer (1GHz Pentium III with Linux OS), which is running two software components; a picture-taking program and a WWW server.

The camera is mounted facing downward to take a picture of the contents of the drawer. The computer controls the camera and extracts the captured images through its connection to the serial I/O port [1]. When a user closes the drawer, the program in the computer detects the drawer-close event through the reed switch, turns on the lamps, takes a picture and transfers the picture to the computer.

A laser diode is located in the upper right-hand corner of the Strata Drawer and projects light diagonally to the lower left-hand corner of the drawer below. A cylindrical lens is placed in front of the laser causing it to project a line of laser light across the contents of the drawer. Where the Timestamp Drawer captures the time of the close-drawer event, the Strata Drawer takes a picture of the drawer contents. After taking a picture and turning off the lamps the program turns on the laser and takes a

[1] http://photopc.sourceforge.net/protocol.html

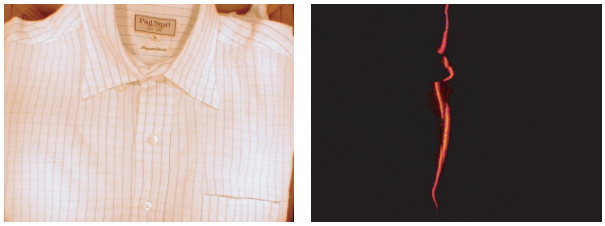

Figure 3: After taking a picture in the drawer (left), the picture-taking program turns on the laser and takes a second picture of the drawer contents illuminated by the laser line to determine the height of the drawer contents (right).

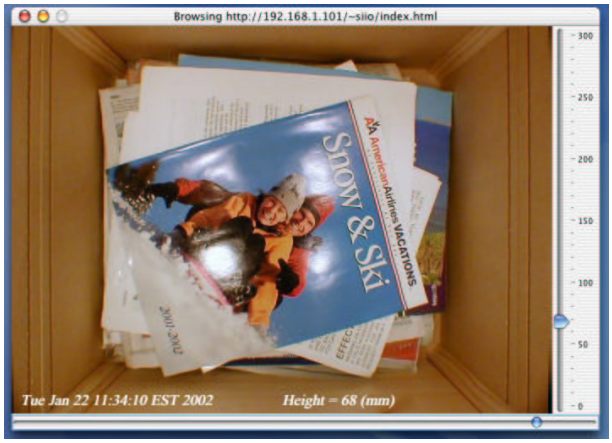

Figure 4: The Strata Drawer has time and height sliders to browse through the stack of objects that are in the drawer.

second picture of the drawer contents illuminated by the laser line. This results in a set of images as seen in Fig. 3.

Since the laser beam shines diagonally across the contents of the drawer, the height of the contents is measured as the distance from the edge of the drawer to the line drawn by the laser. The further the line of laser light is from the left-hand edge of the drawer, the higher the contents in that drawer. Since objects placed in the drawer are not necessarily flat (the shirt for example), the program calculates the weighted average of the distance to this line and determines the height by interpolating a premeasured value.

The first picture taken by the camera is placed on the WWW server with a timestamp along with the measured height information. A dedicated browser for the page has been written in Java and shown in Fig. 4. This browser provides the user with time and height sliders to navigate the captured images. Since these images are on the WWW, browsing can be done from any computer with access to the Internet.

The Strata Drawer has been used in our office for more than two months, to keep a stack of papers that were previously left out on one of the authors' desk. During this period of time the Strata Drawer and browser were used with good effect by the author to locate personal documents such as bank statements or product leaflets, without opening the drawer.

When documents in the drawer are removed, the stack information may be imperfect as the drawer is not keeping track of individual contents or the sequence in the lower stack. When the stack becomes lower, the current system simply warns that the displayed document may not exist in the drawer by changing font color for the height indicator. During the feasibility test period however, this was not seen as a problem since we used the drawer to store such documents found in a stack of papers on people's desk. These kind of stacks are not accessed frequently, with the result that significant changes in the stack rarely take place. As the stack keeps growing with little removal, the drawer will be full in time. Once the drawer becomes full, we could remove all the documents, pack them in a corrugated box and write the URL to the strata pictures on the box.

5 Peek-A-Drawer

5.1 Family Communication

The nature of our personal lives is changing. We no longer live in co-located extended families. Instead we have adopted economic mobility over geographic stability. Because of these decisions we frequently find ourselves living across the country from members of our extended family. Grandparents, though distant, still want to share a part of their living space and their lives with their grandchildren. They want to know about their grandchildren's favorite toys, their artwork, schoolwork and all those things that would be naturally shared if they lived close to one another.

While we can already share our lives using current electronic tools such as email, digital cameras, and video conference / telephone systems, these are lacking in two respects. First, they are not as easy to use as many appliances that provide a single function and simple operations such as putting something in and pressing a button. Secondly, these electronic tools require a deliberate action to activate communication. They are not as lightweight as simply storing something away in a shared drawer in a home.

5.2 Prototype

To support communication between extended families, we have chosen a drawer in a chest of drawers as a space to share with a distant person. A chest of drawers already

Figure 5: Overview of the Peek-A-Drawer. The photograph of the upper drawer in one cabinet is displayed in the lower drawer in the other cabinet.

functions as a storage unit and family members in a home often share its contents. For this reason, it seems like a natural choice to augment drawers to provide a virtual shared space for use by people in separate homes.

As shown in Fig. 5, we have made a pair of the Peek-A-Drawer prototypes by using the same kind of three-drawer chests used in the Strata Drawer prototype. As before we have also removed the top drawer, and have equipped it with a digital camera, halogen lamps and a reed switch. Different from the Strata Drawer, we made the chests with two drawers each, and equipped the camera to take picture of the contents in the upper drawer.

In the lower drawer of each chest we have installed a computer (1GHz Pentium III with Linux OS), a 15-inch LCD and buttons for navigation. The pictures taken by the camera are shared over an Internet connection between the computers in the two chests. The LCD in the lower drawer of one chest displays images of the contents of the upper drawer in the distant chest. Placing the LCD face up in the lower drawer provides the illusion that the user is looking into the distant drawer.

The computers in each of the chests are running three software components: a picture-taking program, a WWW server, and a picture-browser. When a user closes the upper drawer, the magnet in that drawer closes the reed switch. The picture-taking program detects this event, turns on the lamps, turns on the camera, takes a picture inside the upper drawer and retrieves the image from the camera. After compensating for the barrel distortion caused by the wide-angle lens, it assigns a unique name and places the image on the WWW server's file directory. The picture-browser in one chest periodically checks the WWW page in the other chest and gets a new picture file when it becomes available. When a new picture is available, the program plays the recorded sound of a drawer-open/close event to indicate that the upper drawer in the distance has been accessed.

5.3 Discussion

Technically, the same communication function could be realized by designing another configuration of a digital camera with automatic data transfer ability. We could adopt a mobile camera or a wall mounted camera to enhance image variety by shooting objects outside drawers. But by constraining the camera's use to a closed, well defined, fixed space (inside a drawer) we believe our Peek-A-Drawer configuration addresses certain privacy and usability issues.

First, parents would be justifiably reluctant to give their children a hand-held device capable of transmitting images, viewable on the web, that could compromise the details of the intimate inner workings the family home. Second, when asked about having an on-line camera device in their homes people express privacy concerns, even if they "know" that the camera does not take a photo until it is activated. For this reason we did not design a system that takes pictures in a fixed, more open space such as a specified corner of a room, or of a table. Third, novice camera users such as children will benefit by a fixed camera, because the picture will automatically be in focus, properly exposed, not blurred, white-balanced, and well composed. Finally, the image that is displayed is full size. These equal-sized pictures being displayed in the equally-sized drawers will help small children better understand the size and details of the remote objects.

5.4 Field Test

A field test of the Peek-A-Drawer was carried out for 6 months. A pair of Peek-A-Drawers was installed in a couple of families: in a home of a granddaughter who was 11 years old, and of a grandmother who was 72 years old and living alone in a different city about 300 km distant. During the test period, 200 pictures were transmitted between the two families.

The drawers were highly prized by the grandmother who was excited about it and had found that the device to be more indispensable than expected. She was sending picture postcard-like photos of small dolls and other articles arranged in the drawer with message cards. In addition to these postcard-like pictures, she sent pictures of fruits and flowers picked from her garden, heirloom-like articles, and anything that might be of interest to her granddaughter. Although the granddaughter seemed to be less excited than her grandmother, she was nevertheless constantly putting her favorite things in her drawer, and looking forward response from her grandmother. Ob-

jects related to the granddaughter's recent activities such as beachwear, a paper bag with a resort hotel logotype on it, brochures of a museum, and a swimming competition certificate had been sent. Both of them said that the drawer was so easy to use, that sending messages was enjoyable and its use was not bothersome at all.

Sometimes the kid's picture was not self-explanatory, prompting the grandmother to include a message in the next picture, inquiring as to what it was. This resulted in an alternating exchange of several pictures. In some cases, the grandmother asked the kid's parent about the drawer's contents by either e-mail or telephone. Thus this device produced opportunities to communicate with the entire family. The sound of the opening drawer that was played when a new image is received provided lightweight cues about the aging mother's activity and was a source of comfort to the parents about her well-being.

In the beginning months, these drawers were not used for storage as we had originally imagined their use. Both the grandmother and granddaughter emptied the drawers before placing a new item in them. One reason for this may be that they want to make the newly included items stand out and to maximize the communication function. After a longer field trial, however, use of the device changed . One day near the ending month, the kid's mother put the transmitted items that were set on the top of the chest of drawers away in the drawer. After that, the drawer was used for storage. On the grandmother's side, however, a unique, unforeseen use was observed. A stuffed doll that had been placed in the drawer some time earlier was taken out and given to the grandchild on the grandchild's next visit. She was using the drawer to keep potential gifts to attract her granddaughter.

6 Meeting Pot

6.1 Office Communication

The modern office environment, where people collaborate using a computerized network, is a formal, efficient way to perform work as it exists today. However, new ideas and new styles of working are not produced just by providing an efficient office environment. Supporting informal communication between people is important in offices that are isolated by partitions and walls. Informing them that a colleague is having a coffee break in an open, communal space, will foster this informal communication.

Communication between family members could also be supported if a coffee break event is transmitted in a house. Sending a coffee-making event from an elderly family member who lives alone and at a distance, can be a efficient notification of their continued safety to other family members, with little privacy concern [7].

To encourage informal communication at the coffee break space in an office, we have implemented a Meeting Pot system. This system informs colleagues in their office that people are meeting in the open space for a coffee break. By installing this system, we can facilitate informal office communication, by providing office workers cues that they could join the coffee break.

There are two design issues of concern in this system: How to detect the situation in which people are gathering for a coffee break, and How to inform the rest of their colleagues.

6.2 Detecting a Coffee Break

Technically there are many methods to detect the situation in which people are coming to the open space for a coffee break. It can be detected by sensing video, audio, vibration or the infrared radiation from human bodies. By using these sensors alone, however, it is difficult to discriminate between coffee break events and other meeting events. Moreover, capturing images and sounds may raise some privacy concerns.

The method adopted in this study is to detect coffee break events by monitoring the operation of the coffee maker that is installed in the open space. Recently, an Internet service has been commercialized that senses and transmits the activities of a remote elderly individual or couple through their electronic teapot [7]. The service provider mentions that they can alleviate privacy concerns by detecting human activities indirectly through activities of appliances.

6.3 Coffee Aroma Generator

Though the information that people are meeting for a coffee break is important for promoting informal communication, it is of a comparatively low priority in daily office work. We have decided to present coffee maker usage in an ambient manner, that is, to present it as a weak stimulus that is near the perceptual threshold of an office worker [5]. If it is presented in this ambient manner, people can ignore it easily when they are busy. Among several possible ambient display methods that could be used to notify the occurrence of a coffee break event, we have chosen the smell of coffee, and have implemented the coffee aroma generator.

Figure 6 shows the Meeting Pot system, which consists of an augmented coffee maker and 5 coffee aroma generators. The coffee maker has been remodeled to transmit radio frequency (RF) signals when the heater is turned on to prepare coffee. The signal from the RF transmitter is received by the coffee aroma generators. It reaches about up to 100 meters without obstructions. In the feasibility test in a real office environment (discussed later), the

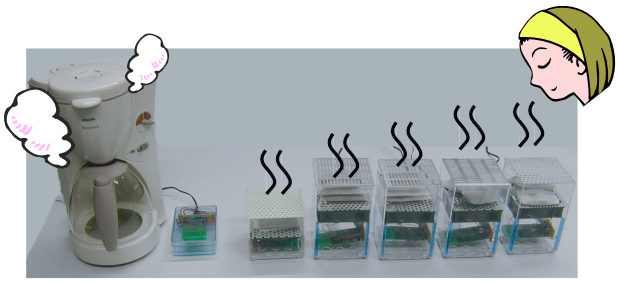

Figure 6: The Meeting Pot system, shown with an augmented coffee maker and 5 coffee aroma generators.

system covers all 5 floors of our faculty building.

The coffee aroma generator contains a fan, an RF receiver and instant coffee powder. The fan in the coffee aroma generator is activated when an RF signal from the augmented coffee maker is received, and emits the aroma of the coffee by blowing air through the freeze-dried instant coffee powder installed above. The thin plastic film lid on the top fulfils the role of the valve, and keeps the coffee aroma from being emitted when the coffee aroma generator is not activated. We utilize instant coffee powder instead of milled coffee beans, because the beans spoil in a few days. Our design using instant coffee powder has a maintenance advantage also, as it emits a constant quality of smell for several months.

In summary, the Meeting Pot system transmits coffee aroma to remote locations, wherever the coffee aroma generators are located, when we use the coffee maker. It is a natural, ambient way to notify others that people are meeting for a coffee break.

6.4 Feasibility Test

To test the feasibility of the Meeting Pot system, we have installed the augmented coffee maker in the common room, and 5 coffee aroma generators in the faculty offices of the Future University-Hakodate. Additionally, the signal from the coffee maker is also received by a server computer, which also sends electronic mail and updates the coffee maker status on a WWW page.

We selected 10 subjects from faculty staff, and divided them into two groups of 5. One of the groups has the aroma generator installed in their office, and the other group receives an email that says coffee will be ready in a few minutes. After 8 weeks of use, the subjects were exposed to the other form of notification for the final 8 weeks.

We interviewed all subjects about the system after the end of the 16 week experiment period. Many of the subjects believed that the system encourages their informal communication very naturally by telling the coffee is ready in the common room. Most subjects preferred coffee aroma generators over the email notification. Although some subjects expressed the desire to know who is in the common room, they did not want their own behavior to be detected in the room in order to provide that additional information. This conflict illustrates a typical privacy issue found in sensor-based CSCW systems, including ours.

Interestingly, when a coffee smell came, some of the subjects took breaks by going to a smoking area or some other common area where colleagues are gathered. A coffee smell reminds them to have a break and to converse with colleagues not just that coffee is available.

With our system, we could use different aroma generating substances other than coffee, (flowers, for instance) but given what we saw in the subjects' behaviors, coffee aroma has a rich cultural meaning that evokes communication implicitly.

In our study there were times when the subjects could not go out of the office to join colleagues because they were busy with their job. Even during that time, many felt relaxed having an awareness that their colleagues were on a break. Occasionally when this happened, they took a short break by themselves. While we tested our design in a co-located work setting, we believe that the system can extend to provide a comfortable, ambient awareness of family members in the same or remote locations as well as office workers in remote locations.

7 Related Work

7.1 Drawers

TouchCounters [12] is a system with storage containers and a shelf. Each container has a display and the shelf has sensors to identify the containers. They can be used to manage the contents efficiently by providing usage information for each container. The Timestamp Drawers also focuses on the event of use for each of the drawers to find items. By adopting drawers that have a positional constraint, we have omitted the sensors required to identify containers. In addition to the positional constraint we also included the ability to include text annotation by keyboard and by voice recognition.

HomeBox [8] is a set of drawers designed as a WWW content creation tool for people in the developing countries. Users can arrange the contents of the drawers and create their WWW page wherever a scanner and an Internet connection is available. Although the main purpose of this system is to realize efficient use of computer resources by batch processing, it also demonstrates the ease of use afforded by an everyday set of tool drawers. In contrast, Strata Drawer focuses its effort on content retrieval, and Peek-A-Drawer focuses on one-to-one communication. Additionally, both Strata Drawer and Peek-

A-Drawer have an onsite camera, a built-in server and a built-in browser to support these interactive operations.

7.2 Communication Decor

Peek-A-Drawer and Meeting Pot address lightweight human communication concerns similar to those addressed by the Digital Family Portrait [6]. The Digital Family Portrait is designed to be an electronic representation of a distant family member, typically an elderly family member, that provides a qualitative sense of that person's daily activity. Like a traditional portrait, it is intended to be hung on the wall or propped on a mantle, blending with household decorations. Peek-A-Drawer also supports communication between distant family members and is also intended to support lightweight communication between grandparents and grandchildren. As such, both qualify as Digital Decor. There are two predominant differences between these devices. Peek-A-Drawer is completely symmetrical in that each end of the communication has exactly the same device, and Peek-A-Drawer supports a two-way communication channel where Digital Family Portrait is one-way only.

The i-pot and mimamori-hot-line system [7] is a commercialized Internet service to provide information about the operation of remote electric teapots used by elderly singles. This service aims to inform younger family members whether the remote elderly family member is healthy or not. While the Meeting Pot system utilizes similar sensing techniques its main focus is on facilitation of informal office communications.

The Elvin is a notification system for the networked office environment which has a CoffeeBiff button that is used to tell colleagues of a coffee break [4]. While the Meeting Pot also informs colleagues of a coffee break underway, it detects the coffee break automatically and notifies colleagues in an ambient manner using the aroma of coffee.

There have been many studies and attempts to use aroma displays to enhance the reality in a cyberspace, such as [2] and [3]. They use aroma as a realistic foreground display to augment graphical virtual world, while we use it as a symbolic ambient display in a daily office environment.

8 Summary and Future Work

We have described Digital Decor, computer augmented everyday things, which will be in the mainstream of ubiquitous computing. We have focused on two application areas, smart storage and informal, lightweight communication. We have built two prototypes for each of the two application areas and begun formative evaluation.

Our plans are to evaluate our prototypes in everyday use. The Timestamp Drawers and Strata Drawer will be used in authors' office for a long term. Meeting Pot will be used continuously in the faculty meeting room. We hope to be able to share the results of this further evaluation in the very near future.

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