Interaction Design for Home Information Appliances

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ABSTRACT
This paper describes the design and evaluation of a prototypical information appliance for displaying and exchanging paper and electronic notes and pictures at home. This study addresses two research problems: how to provide minimal and relevant functionality to home users and to investigate novel interaction styles that rely on a combination of computer-vision based technology with commercial pen input devices in order to support easy and learnable interaction. Evaluation of the prototype application suggests that participants were quickly able to use the application and that they liked the idea of combining paper and electronic media.

KEYWORDS : Information appliances, home messaging applications, graspable user interfaces.

INTRODUCTION
This paper describes FRIDGE, an experimental prototype of a mixed-reality messaging appliance for the home, that supports message exchange and display for a household, whether that is paper-based or electronic. FRIDGE has been demonstrated in a video form at the ACM conference CHI 2001 [10]. This paper reports more extensively the rationale of its design and the results of its evaluation.

One main motivation for designing and developing FRIDGE has been to gain understanding into the type of information appliances that will furnish the future homes, where computing and internet access will appear in ever more facets, and will become distributed amongst every-day objects rather than centralised in a single PC (as happens currently in households where internet is used). A second, as important motivation, has been to study interaction styles suitable for in-home information appliances. In the home context the usage of home information appliances must be assumed to be incidental. The target user population is more diverse than for a work-related context. Users are unlikely to read a manual and are even less inclined to spend much effort to use their appliances. Below we introduce the type of activities that FRIDGE is designed to support, the design approach, and our first findings from its evaluation and the current evolution of our research.

RELEVANCE AND RELATED WORK
People often use fridge-doors, pin-boards, or even doors, to post bills, leaflets, photographs, postcards, etc., to maintain shopping lists, to leave messages to each other, or reminders to themselves. The fridge-door in particular is so popular that special products are marketed to support this paper-based activity. Fridge-mag for example (figure 1), is a Plexiglas-cover of the fridge-door, behind which pictures are displayed, thereby replacing the common magnet holders. This product is marketed in the United States, where the habit of displaying pictures and messages on the fridge seems to be more widespread.

The exact habits of people, the location and surfaces they decide to use, the form of the paper they use, the location in the house, varies across housholds and across cultures. E.g., Europeans may be less prone to use the fridge door as described above, and a different type of messaging takes place in a student house-share vs. the houshod of an elderly couple. We contend that displaying brief notes, postcards and pictures of loved ones, will take place in one form or the other in almost every household, albeit in different forms and in different locations. Our design aim has been to provide an easy to learn and enjoyable interaction for this activity.

In the last two years the consumer electronics industry has announced/exhibited home appliances augmented with computing and Internet connectivity. Samsung has recently announced such a microwave oven and Electrolux, see figure 1, has exhibited a ‘smart’ fridge called the ScreenFridge at consumer electronics shows. The interaction with such devices is largely through touchscreens and is comparable to current desktop devices. The media involved is purely electronic unlike the present work, which aims to mix paper and electronic media. The proposed uses of the Internet connectivity is for automating home shopping or for finding recipes. Contrary to inventing activities that could be supported with such devices, this research investigates how a widespread and already established activity, based on paper, can be augmented through this emerging generation of home appliances.

Figure 1 : Fridgemag (left) from www.fridgemag.com from Electrolux is a low tech product for displaying pictures on the fridge. The ScreenFridge (right) product by Electrolux. From www.electrolux.co.uk/screenfridge.

The combined use of paper and electronic artefacts for supporting an existing paper based activity, is a concept that has attracted considerable interest in the field of human computer interaction. A pioneering work was the DigitalDesk developed at Xerox [11]. Similar to that system, the computer output in the FRIDGE system is projected on a white physical surface, which for Fridge is envisaged to be any surface in the home that is preferred by the residents, e.g., a cupboard, a table-top, or a fridge door (hence the name of the demonstrator). In practice, for our prototype, the computer image was displayed on a white desk surface. On this desk, paper and electronic notes and pictures coexist. Compared to other investigations of systems augmenting paper use, e.g. [3, 7, 8, 11], this prototype is intended for a home context: both functionality and interaction need to be considerably simpler.

FRIDGE supports free hand pen-input, with no handwriting recognition involved combined with a graspable user interface [4]. Graspable interfaces allow the manipulation of electronic objects through physical handles, as opposed to virtual handles (like a cursor) which is the traditional form of desktop interaction. These interfaces are arguably (see [2]) more natural on the grounds that they offer richer affordances than conventional selection techniques. Among several other benefits, they enable two handed input, truly parallel input by multiple users, and leverage off our well developed, everyday skills for physical object manipulations [4]. The interaction can be more direct than with a traditional pointer and cursor based system, because electronic objects can be selected directly by grabbing their physical handle rather than by selecting them first.

As will be explained in the next section, the handles are tracked using computer vision techniques, using VIP, a system that was developed in the Eindhoven University of Technology. This approach was first demonstrated with the BUILD-IT system [8]. Current research with the VIP, explores its application for supporting the early phases of architectural design, which rely heavily on paper use [3], and as an input technique for volumetric data visualisation [4].

TECHNOLOGY AND RATIONALE FOR THE DESIGN

The Fridge prototype is running on a single Intel Pentium II PC. The hardware set-up includes: A beamer projecting the output on a tabletop surface, pen input through a pen input device, and a graspable user interface via the VIP system. These components are detailed below.

Mimio of Virtual Ink is a commercial high-resolution ultrasonic position capture system, that augments writing with a marker pen, with the ability to input the free-hand pen input to the computer. The Mimio stylus is an untethered device, which feels like a chunky and weighty marker pen for a whiteboard. The stylus of Mimio is also a sleeve for conventional marker pens, which can be attached to this device. The capture bar, is a two feet long device, which is positioned along the input area, where also the computer output is projected.

The graspable user interface is implemented with the Visual Interaction Platform, VIP. VIP works as follows: A camera, placed above the output surface and next to an infrared light source, tracks inch-sized infrared-reflecting patches, turning them into physical handles for interactive virtual objects. Patches canbe attached to small bricks as in the BUILD-IT system [8], or to fridge-magnets, or to pins for a pin-board, etc. The patches are moved over the projected computer display, providing a simple pointing and dragging functionality. This set-up is similar to the meta-Desk by Ullmer and Ishii [9], which, however, used backprojection. Compared to earlier graspable user interfaces, such as those of the Active Desk experimental system [4], the advantage of this input technique is that the graspable handles are untethered so they are more agile. The user interacts by modifying the location and the orientation of the bricks. Unlike desktop environments where mouse actions and cursor movements occur at separate places, visual feedback in the VIP system is shown where the bricks actually are.

The video captured by the camera is processed with VIP++ . This software consists mainly of a C++ library that was developed in-house to support video-based interaction. Camera images are acquired by means of a Leutron Vision frame-grabber card and the Daisy Library (see www.leutron.com). A fully automated calibration program projects a test pattern that is subsequently captured by the camera and analysed to establish the transformation between both device co-ordinate systems. This calibration is required in order to guarantee that the visual feedback provided by the projector occurs at the actual brick positions. The image analysis in the VIP is fairly simple: First, a "flood-fill" algorithm identifies regions in the image that share a common value (i.e., the white blocks). Then, a labelling algorithm selects connected regions in a binary (black and white) image and calculates features such as area, moments, and principal axes for these regions. These features are used to estimate the position and orientation of the bricks.

Figure 2 shows a snapshot of FRIDGE in action. The mixed display consists of: the paper notes and picture-prints which are affixed on the display, an icon representing a block of electronic notes from which (s)he can take one out, a collection of projected portraits of family members and a note-book icon. An envelope icon is attached to some pictures (both paper and electronic ones).

The functionality implemented in FRIDGE is the following: (a) Notes are created by placing a handle on the notebook icon. Notes can be manipulated by putting a handle on them and moving it. They can be released by hiding the handle (the brick) from the infrared camera, e.g. by tilting or covering the handle. Users can delete notes by moving them out of bounds. (b) User can write and draw on notes using the Mimio stylus. (c) Users can mail a note to one of the persons whose paper or electronic portrait is decorated with a projected envelope icon. Users may receive mail, which is posted on the display on random positions superimposed on previous content.

The two input techniques were combined to avoid overloading a single device with multiple uses. Thus, it was hoped, it should be easier to guess and to remember how to use the system. Thus the pen is not used as a pointing device but only for writing or drawing like a standard pen. Pen-input for writing and drawing is arguably a very natural form of interaction. Children learn to use pens even before they learn to speak. Excluding handwriting recognition is essential to preserve the naturalness of pen-input: first, with physical pens there is no recognition going on, and second, with handwriting recognition technology the user is required to monitor and correct the recognition process. This extra task complicates handwriting unnecessarily for the context of use studied hereby.

Figure 2 : Electronic notes are moved, rotated and stacked in a manner similar to paper notes.

Notes behave similar to paper-slips in several ways. They are not resizable and scrollable, they cannot be 'minimised' but they can be moved, rotated and stacked. Unlike files on a desktop, notes are not grouped in folders, backed-up or recycled. Thus, it is hoped, a simple conceptual model of the interaction should result.

The mail facility is a very limited electronic mail application. The aim has been to make electronic mailing and message posting easily accessible in situations where, normally, it would not be: e.g., replying to a mail that arrives while cooking, or a enabling a child, too young to read and write, to send a drawing to its parents at work. The functionality is similar to SMS messages on mobile phones, but instead of typing through a numeric keyboard it supports free-hand input of the message (therefore supporting drawing or annotation of notes).

USABILITY EVALUATION

Two usability evaluation sessions were conducted. The first was intended to be formative and was conducted with colleagues of the authors, some of whom are also researchers in user system interaction. The second involved paid subjects, who are elderly, without computing, e-mail or SMS experience. Interesting contrasts emerged between the two subject groups. The process and the results of the evaluation are discussed below. We discuss separately issues concerning the prototype usability, the acceptance of the interaction style supported and, finally, whether the electronically and Internet enhanced messaging activity is something that users appreciate or not. The latter helps interpret some of their reactions to our prototype, but also provides indicative (non-generalisable) evidence of the relevance of the design to current needs of people.

Procedure

Subjects were required to fill-in a pre-session questionnaire with the purpose to identify their habits concerning posting pictures, drawings at various places at home, whether they use the fridge or some other place, whether they live alone or with other people etc.

Users were asked to perform all the simple tasks that FRIDGE supports. They were given no directions for using the device, apart from the fact that notes were to be manipulated with the blocks and that the pen was for writing. We gave them enough time to complete the tasks. All users managed to achieve their tasks, although several errors were committed and there was a considerable variation in efficiency.

After the session a structured interview was conducted to collect a feedback about the interaction styles, the functionality of the system, and concerning the concept of mixing paper and electronic activities in such an appliance. Further, participants were encouraged to provide comments through open questions.

Participants

User tests with the first prototype of FRIDGE were performed with eight volunteer participants with extensive computer and e-mail experience and with six participants with no computer or e-mail experience at all. The average age of the experienced participants was 27 years, and the average age of the inexperienced participants was 68 years. The participants represent a range of different households, such as people living alone, living with a partner, and living with either their children or their adult parents.

Pre-test questionnaire

The responses to the pre-test questionnaire show that all participants engage in the type of paper-based activities that we set out to augment. At home participants write messages for others, shopping lists and reminders for themselves and leave them on the table, on a special board, or at other locations, such as on the stairs, near the phone or on the computer monitor (the latter applies to the first group of test users).

Most participants use any piece of paper that is available for writing notes, or sometimes write it in a diary or on the calendar. It is interesting that only one participant displays notes on the fridge-door. Most participants (13 out of 14 subjects) decorate their houses in some way by putting postcards, pictures or drawings on a special board or a flat surface, such as a shelf, piano, mantelpiece or the windowsill. Most are likely to hang up notes such as reminders, messages and shopping lists at a very visible location, although to a lesser extent than displaying pictures. Postcards are given a visible location less often than pictures.

The older and less experienced participants mentioned decorating their house with drawings more frequently than the participants with more computer experience did. Only 2 of our participants post printed material such as newspaper clippings or advertisements. The specific location for keeping the information is important, e.g. close to the phone, or in a central location like your desk. The participants reported that they assign special purpose to different locations and surfaces in the house. This suggests that a single form of messaging appliance, centralised in one location is not appropriate for most people. This confirms the reasoning for migrating home messaging away from the PC but further suggests that this activity should be distributed, and tailored to different locations and displays, e.g., on the fridge, the desk, the television, the telephone, etc., rather than localised on a single device.

Evaluation of the FRIDGE interaction design

Reactions to FRIDGE were mixed. All subjects were able to learn to use the prototype within a few minutes, without help which was the main ‘benchmark’ for our design. Overall, participants found the prototype interesting and fun.

Concerning the relevance of the concept to the users, about half of the non-experienced participants would prefer to preserve their current habits for exchanging and displaying information and would not use something like FRIDGE at home. Despite its simplicity it still appears inferior to paper. On the other hand, most participants enjoyed the mixed reality aspects of the system. Participants without computer experience were less enthusiastic than experts about this feature of FRIDGE, although some overestimated the extent to which electronic notes can or should substitute paper.

An interesting contrast emerged between the two groups of subjects. Some participants with computer expertise missed extra mailing functionality, such as editing and managing of an address book; they expressed the wish to send and post spoken messages and missed the speed of a keyboard. (Note however that on their computers they do not use speech messaging). We contend that this reaction results from limitations of the evaluation procedure. Some of the expert subjects could not stop acting as human-computer interaction experts and, further, the simplicity of the concept cannot be appreciated in a laboratory setting: expert users interrupted their work on powerful PCs for an evaluation session with a stripped down note and messaging application. A more valid assessment of the utility and appropriateness of this appliance, even with the same subjects would be at its intended context (the kitchen), and in its actual daily use. The second group (of non-computer experienced people) were very pleased with the limited functionality provided. Although they were more apprehensive about participating in a user trial, they quickly figured out how to use the system.

The functionality that is provided in FRIDGE was easily understood and used by the participants. For most, particularly the elderly, the fact that it was so limited was appreciated. Some commented on the need to convert printed material to electronic form. Experienced users missed more advanced mailing functionality and connectivity with mobile phones and their PCs.

Assessment of the interaction style

The participants were positive about the VIP input device for non-dominant hand input, although given its experimental state we had anticipated complaints. An initial explanation was first that its novelty made it more fun to use, but also that the tasks for the non-dominant hand were not demanding in precision and dexterity.

Not all users, however, found it easy to manipulate the brick to quickly grab and release notes. Most users started by pulling the handle sharply off the note before developing a strategy of tilting it to the side to hide the infrared reflecting patch from the camera. A few of our more computer-experienced users, remarked on the sluggishness of the interaction (redraw which is normally 25Hz slowed down when multiple objects where on the screen). Some users, did not figure out the necessity of keeping the infrared reflecting material visible from the camera and were puzzled at the behaviour of the system when the reflecting patch was not visible to the camera. An easy remedy would be to make handles flat. Users had most trouble guessing that they should delete notes by moving them out of the interaction space. In some cases notes were lost, when the intention was just to reposition them along the border. Suggested improvements are mainly related to polishing the surface interaction design, e.g., by animations to provide feedback and warnings to users.

In contrast to the generally lenient view to the brick input device, participants were much more demanding for the pen input, although that device is quite robust. Being accustomed to physical pens, all subjects expected resolution, speed and accuracy to match those of standard pens. Notably, one subject, though an experienced computer when the stylus did not respond fast enough, started to shake it as if to make ink flow.

Most participants (11 out of 14 subjects) would prefer combining the functionality of selecting and manipulating the notes with the functionality of writing and drawing in the pen to having two different input media. This seems to contradict the initial design decision of providing two different input devices to increase the naturalness of the interaction. They justified this assuming that it would be easier to have only one device to use, although the simplicity of interaction was precisely due to the use of two dedicated input devices.

CONCLUSION

There are several lessons that can be drawn from the experience reported hereby. The most important ones-from the perspective of the researcher pertain to the limitations of the study as a means to answer the research questions described in the introduction: to assess the appropriateness of a specific interaction style and to assess how the general concept of information appliances will instantiate itself in future homes.

The abstract concept is sufficiently shown by the prototype demonstrator, but the details of how this appliance will materialise as a product for use at home, are quite important for its assessment. Performance limitations that are usually accepted in the laboratory are unacceptable in a realistic context: VIP is very sensitive to variations in lighting, the noise of the beamers used for the projection is not acceptable for a home environment 24 hours a day and configuration of the system must be done by researchers and not the users themselves. Further, we asked our subjects to compare the experience in the laboratory with their daily habits. Very likely, the subjects would have different reactions had the testing been done at home, or at a situation resembling closely their daily life. This observation motivates our current work towards setting up a living laboratory at the Eindhoven University of Technology (see [5,6]). This will be a testing facility where novel technologies can be tested by subjects staying in the laboratory for prolonged periods (from 2 days to 2 weeks). Such a testing facility is crucial for testing information appliances like FRIDGE and more complex technologies, that are colloquially described as 'smart home' technologies. In such cases the environment perceives much of the user activities or needs and tries to provide relevant and timely services. Testing these systems is another case where a short visit in a laboratory would simply be irrelevant: users can assess the learnability of a system but not what benefits or nuisance it would create in their everyday activities.

Concerning the acceptance of augmenting the paper-based activity described in the introduction with the user of rich interaction media and connectivity, our conclusions are mixed. In general we had some positive reactions, but an improved prototype should allow for distributing this activity across multiple surfaces at the home and across various devices with different form factors.

In terms of our declared interest for interaction styles for the home the naturalness of the interaction attained was very satisfactory. Subjects learned easily and quickly how to use the bricks and the pen. In part this was enabled by the simplicity of the application which is the essence of the information appliances concept. The mix of two novel and natural interaction styles proved successful in simplifying interaction, but was unanimously preferred less by the subjects to using a single input device. Current work concerns the exploration of graspable user interface for supporting creative meetings (brainstorming) and for devices for children users.

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