RFID Cards: A New Deal for Elderly Accessibility

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Abstract. Elderly adults face two serious challenges bridging the digital divide. First, many suffer from physical or cognitive disabilities, which inhibit computer use. Second, the "traditional" personal computer interface constitutes a foreign and forbidding paradigm. Consequently, elderly adults are less likely to access the Internet, and this lack of accessibility denies them increased social contact and access to information. This paper presents the design of a tangible user interface (TUI) for an email client that is suited to the physical, neurological, and cognitive needs of elderly users. A review of the TUI literature identifies radio frequency identification (RFID) tagged cards, integrated with standard personal computers, as a viable alternative to the mouse. These cards can represent interaction objects and actions, forming the basis for an interaction language. The email client interaction design illustrates many simple and advanced RFID card interaction techniques.

1 Introduction

The juggernaut of computing technology has largely bypassed a large and growing pool of potential users, older computer users. Consequently, many elderly adults are alienated from a powerful tool that can improve the quality of their lives. The obstacles they encounter include cognitive and physical disabilities and difficulty in developing a mental model of the computer as a tool.

The elderly constitute a significant portion of the population in industrialized countries. A 2000 U.S. Census study put the number of those aged 65 years or older at over 33 million, 12% of the total U.S. population [19]. The online presence of the elderly, however, is shockingly small: a 2004 study reported that only 22% use the Internet, compared to 58% aged 50-64, 75% of those aged 30-49, and 77% aged 18-29 [5]. The negative correlation of Internet use with current age is linked to several factors. Many older people suffer from some sort of disability such as decreased vision or hearing acuity. The 2000 study (ibid.) reported that 42% of those over 65 have such a disability, compared to 19% of those aged 5 and older. Besides physical barriers, the elderly also experience age-related cognitive changes that inhibit learning and their use of computers. Older adults show a decline in both episodic and spatial memory

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[9, 12]. Psychomotor abilities decline with age [23], and older users have more difficulty positioning the cursor over small targets [21].

The small percentage of older Americans using computers and the Internet is particularly regrettable because these tools have great potential to improve the quality of their lives. Social interaction and support can have profound effects on emotional and physical health, but transportation expenses and lack of physical mobility make social interaction difficult for many older adults. The Internet offers the promise of an effective and low-cost medium for social interaction [22]. For example, older Internet users are just as enthusiastic as younger users to send email: 94% of older users as compared to 91% for all users [5]. On SeniorNet, a nonprofit organization of computer users aged 50 and older, popular activities include emailing family and friends, making and managing photos, conversing with friends, and creating greeting cards [18]. Another potential benefit of computing technology is the ease of access to information. For example, the Internet has become a rich source of knowledge about health issues [2, 11, 16].

There is evidence that user interfaces (UIs) present a significant barrier to the elderly. Physical and cognitive barriers suggest that the windows, icons, menus, and pointing (WIMP) UIs so prevalent in today's computing technology are not the most appropriate for this population. Particularly problematic is the ubiquitous use of menus and pointing tasks [13], both of which tax the decreased memory and motor skills common to the elderly.

There are potential alternative computer controls and input devices. Radio frequency identification (RFID) technology makes new interaction techniques feasible. RFID technology is now an affordable alternative to the mouse as a computer input device and suggests techniques for making computers more accessible by mimicking everyday tasks and providing a more tangible, less abstract interface. We also believe that tangible user interfaces (TUIs) can facilitate computer literacy by enabling new paradigms more appropriate for casual computer users. The standard desktop metaphor is appropriate for sophisticated computer users with many tasks to perform simultaneously, but not for those who typically perform tasks sequentially at an unhurried pace. Multiple windows break up the visual space, confusing casual users and decreasing visual real estate that could be used, for example, to display larger text. Currently we are exploring the implementation of TUI using RFID technology and the potential of RFID technology to replace mouse and keyboard actions with ones that are more feasible for persons with mild cognitive and physical disabilities.

In this paper we propose alternative interaction techniques using RFID tagged cards and describe the design of an email client using RFID technology.

2 Review of Tangible User Interfaces

Ishii and Ulmer [7] expressed the goals of TUI as "augment[ing] the real physical world by coupling digital information to everyday physical objects and environments." They defined five generic TUI tools with close analogy to WIMP interface objects and demonstrated their use in three applications. Although categorizing TUI objects as transformations of WIMP interface objects restricts the TUI vision, their demonstrations made clear that TUI is more than a transformation. The WIMP to TUI transformations does provide a categorization, albeit incomplete, and a means to measure the progress of the HCI community and industry to achieving TUI. However, in the intervening ten years only one of the five generic tools, the physical icon (phicon), has been developed sufficiently to render it affordable for commodity PCs. RFID tagged cards constitute a viable implementation of physical icons and are mass produced, and RFID readers are becoming more affordable.

Physical icons are powerful interaction tools. Clicking an icon can specify either a task or an object. Selection of multiple icons can represent the subject, task, and object of the task, i.e., a set of icons can represent a complete sentence in verbal communication. Because the computer is aware of the icon-sets' context, icons have multiple or modal meaning, so the number of required icons can be limited. For example selecting the "save" icon with an unnamed icon while viewing a web page can save the web page's URL to the unnamed icon. Later the saved URL icon can be loaded into a browser simply by selecting the icon. In addition, the usability benefits of replacing screen icons with physical icons should not be overlooked. Fitzmaurice and Buxton [4] demonstrated that selecting and placing physical icons is much easier than selecting icons with a mouse on a monitor. Physical icons have inherent meaning that even non-computer users understand. For example, almost everyone understands the meaning of placing a card in a card game or exchanging business cards. Manipulation of physical icons is more understandable and consequently provides more user confidence. The permanence of physical icons "potentially leaves users with more confidence and a stronger sense of control over the status of the interaction" [17]. Users tend to find auxiliary uses for physical items in a workplace setting, which they can tailor to their own needs [6]. Physical icons can also be personally adorned with pictures, text or Braille, making them more accessible.

We were inspired by the UIs described by Jacob *et al.* [8] and Davidoff *et al.* [1]. Both interfaces use RFID cards as physical icons representing objects of the task. Jacob *et al.* use a grid of RFID readers embedded in a Senseboard, a large board for scheduling conference presentations. Presentations are represented by RFID blocks and magnetically mounted on the Senseboard. The interface demonstrates how TUI can add computer support to a task that is traditionally performed by sorting cards on a table.

ElderMail, a TUI email system for the elderly developed by Davidoff *et al.* [op. cit.], uses RFID cards to represent email addresses. This TUI reduces initial learning costs by modeling the UI as an instruction manual on top of a fax machine. Users select the task by opening the "book" to the proper "chapter" and complete the task by reading instructions and inserting RFID cards into slots built into the "book." The final page reveals a scanner bed to place handwritten letters and send the scanned document as an email attachment.

Although this approach demonstrates how a novel TUI can reduce initial learning costs, we suspect that users will quickly tire of turning pages after just a short learning time. This illustrates an interesting tension in TUI design: while physical icons are familiar and therefore good for learning, a slavish adherence to physicality can limit users who have made it over the learning curve. Older computer users do not want to be treated as novice users forever. As they gain confidence and ability they should be allowed to take advantage of the flexibility and efficiency of the new technology.

RFID cards representing personal information like email addresses demonstrate a general benefit of physical icons: because the cards are portable, they can remain in the possession of the user. In addition, the cards can be used like traditional cards, meaning users can exchange email addresses by exchanging cards offline. As the well-known ethnographic study of air-traffic control centers demonstrated, users can develop their own uses for physical icons, beyond those originally intended by the designers [6]. Playing card games is a popular recreational activity among this user group, so they have already mastered the skill of laying down and manipulating card sized objects. By replacing the "book" with a short training session, we believe that ElderMail can be simplified while retaining its critical benefits: reducing user memory overhead and pointing tasks.

Both Sensorboard and ElderMail are bulky interfaces developed for a single task. Although they perform their intended tasks well, they do not address the use of TUI in a general PC computing environment. We believe that TUI devices can be integrated into general purpose computer environments and improve their accessibility and usability for older computer users.

3 RFID Card Interaction Techniques

Several interaction techniques are possible using RFID cards with a single reader, and more are possible with multiple readers. Below is a short list of RFID card interaction techniques. All of these techniques can be used in combination, resulting in a large variety of interactions.

- Card selecting – a selection is made by placing a card on the reader.
- Card context – the meaning of a card depends on the other cards on the reader.
- Time sequencing – the meaning of a card depends on when a card is placed on the reader and the cards preceding and following the placement of that card.
- Position sequencing – the meaning of a card depends on which reader in an array of readers the card is placed on.
- List manipulation – Cards on an array of readers can represent a list and the user can manipulate the list (*e.g.,* rearrange the card order or select alternatives).
- Labeled sequencing – the user can label the readers in an array by the cards initially placed on them. Subsequently placed cards designate set membership represented by the reader.

Time and position sequencing can represent commands issued to the computer using a simple sentence structure:

action [options] [direct object] [indirect object]

RFID card interactions can imitate this simple sentence structure using either time or position sequence. Using time sequencing, the temporal order of placing the cards would determine which cards are the direct or indirect objects. Using position sequencing, the placement of the cards on a reader in an array of readers would determine which cards are direct or indirect objects.

List manipulation interaction techniques make possible the selection of websites resulting from a web search and the labeling of RFID cards. The result of a web search is a list of possible web sites to visit. After making a key word search, the user can populate the array of readers with new RFID cards. The computer system would automatically associate the new cards with the URL address. Replacing a card on the array of readers with a new card could designate that the associated web site is not of interest and to add a new web site to the list. Removing a card from the array of readers and placing the card on a reader designated as the *command reader* could issue a command to the web browser to visit the corresponding web site. If the selected web site is not interesting, the user can immediately visit another web site by placing another card from the array of readers on the command reader.

Labeled sequencing is an interaction technique for the user to define categories and sort a batch of cards into the categories. Consider the process of managing digital photos. After taking pictures with a digital camera, the user downloads the images to her computer. The user sequentially reviews the photos. When the user decides to save a photo, a label printer makes a thumbnail image to adhere to the RFID card. If the user had anticipated the categories for sorting the photos, the user could place a RFID card representing the category on the reader and the photo would automatically be sorted into that category. But defining the categories without first previewing all the photos is difficult. More natural is for the user to preview all the photos, making RFID cards of the saved photos, and then to decide on the sorting categories. RFID cards representing sorting categories can be placed on each reader in an array, then the user can sort the photos by stacking the RFID cards representing the photos on the readers.

The readers in the array can be implicitly labeled. Consider an implementation of the game of single-handed bridge using RFID cards and readers. Three readers are arranged to represent the virtual players around the table, and a fourth reader in the center of the table for placing the card in play. Playing bridge begins by dealing playing cards with RIFD labels on the three readers and to the user. Dealing the cards is effectively sorting the cards into four categories, one for each player. Play continues by the user making bids and plays by placing RFID cards on the play reader, with the computer responding by displaying bids and played cards on the screen.

The fundamental principle underlying all the RFID card interactions above is that the RFID card contains a key to a database resident on the PC, server or Internet. Laying an RFID card on the reader triggers a lookup into the database for the entry with the key on the card. An analogy to natural language is that cards are words and the database is the dictionary containing the meaning of the words. But because the system is aware of the context of the card, it can choose between multiple meanings for a word. The analogy of natural language can be extended. Sentences are ordered sequences of words; as in natural language the card sequence can be constructed in either time or space. Listed manipulation and labeled sequencing interaction techniques are particularly interesting because they transcend the natural language analogy for card interactions and demonstrate card interactions that exemplify tangible interaction techniques and the full advantage of tangible interactions.

4 RFID Card Email Client Design

The HCI literature has clearly identified that UIs for the elderly should employ slower on-screen motion [15], larger font sizes [20], and increased contrast [14]. We observed the need for these design principles while teaching basic computer skills to older computer users. We also observed that using the mouse and knowledge of basic computer use are major barriers to effective and enjoyable computer use. A good match between the user's cognitive model and an application's metaphor results in a natural and fluid user experience, while a poor match leads to errors and frustrations [3, 10]. We also observed that older computer users typically perform computer tasks sequentially at an unhurried pace, unlike younger users, who perform multiple tasks simultaneously. The process of sending and receiving emails can be simplified for users who do not require the flexibility demanded by expert users. And the application's metaphor and interaction style should conform to principles of a simple single-function interface performed sequentially. Our RFID card email client will conform to the following general design principles.

- minimal or no mouse pointing
- low functionality with sufficient flexibility
- uncluttered, high contrast, visually clear displays

These design principles support each other. Simple low functional interfaces will encourage visibly uncluttered graphical interface and allow more monitor space for larger fonts. Higher contrast and larger fonts will make more apparent the possible selections and the current selected item. Limited functionality will reduce many of the selections required in higher functional interfaces. Correspondingly, a design goal to reduce mouse pointing will encourage the low functionality interface goal.

There are a few design goals that are specific to an email client for older computer users. Modern email clients mimic standard postage mail by dividing the process of communication into sending and receiving text documents. Our RFID card email client should adhere to this established division of tasks. While instructing older users, we learned that older users were very specific about who they wanted to send an email and from whose email they wanted to receive, typically relative and friends. This unambiguous and precise delineation of correspondents should be realized by an email client for older computer users, especially in light of the current proliferation of spam in email. An email client for older computer users should severely filter email. Not only will email filtering fulfill the older users' desires, but will enable simpler interfaces.

4.1 Writing and Sending Email

Since sending email is initiated by the user and involves a small number of objects (message body and recipient email address), the interaction design can and should be simple and straightforward. A TUI can reduce the process to laying down four RFID cards on a single RFID reader and entering the message. The four cards identify the user, the task, the object of the task, and task completion. For example, the user would first place a "login" card on the reader and then lay down a "send email" card retrieved from a "Rolodex." The system would open the email client ready to accept the user's message.

The graphical interface can be very simple and uncluttered. It can display the task, "Send Email" and the recipient in a large title bar. The rest of the screen is a blank text field, labeled "Message."

The text of the email can be entered by typing the message or by scanning a handwritten document. While the “send email” card is on the RFID reader, the system can display the scanned image in the message text field. The user can continue to add to the message by typing or scanning additional images. Note that this naturally allows users to intersperse text with images.

At any time the user could lay down a card identifying the email recipient, “recipient” card, and the recipient’s name appears in the title bar. Finally, laying down a “deliver” card from the Rolodex would send the email. Picking up the cards before laying down the “deliver send” card would cancel the email. Users could add more recipients by simply laying down more “recipient” cards.

4.2 Receiving and Reading Email

Receiving and reading email is more complex than sending email, since the number, source, and content of the messages do not originate from the user. However, a restrictive email filter can insure that the number of incoming emails is small enough to be managed by list manipulation interaction techniques. The configuration of RFID readers consists of a command reader and short array (perhaps 4 readers) of list readers. Again the user is identified by laying down the “logon” card on the command reader, and laying down the “inbox” card, which opens the email client to the inbox window.

The graphical interface of the inbox covers the monitor’s screen and consists of a title bar, labeled “Email Inbox,” and a short list of incoming email. Initially the list is empty. As the user adds new RFID cards, cards with keys that are not in the RFID database, to the list readers, the list of incoming email is populated with the correspondents’ names and subject lines. Replacing a new card will display a new incoming email on the inbox list.

The user can read an email by moving a card from the list reader to the command reader. The inbox window changes to display the message, both simplified header and correspondence text. The user can view a different email by exchanging the new email card with any other card from the list readers. The user can choose to delete, save or reply to the email but laying the appropriate command card from the “Rolodex.” The command is completed by picking up the command card with the new RFID card. In the case of deletion the new RFID card can be reused on list readers a display another new email in the inbox. In this way the user can move through a list of incoming emails. When saving an email, a label printer makes a label with the correspondent’s name and subject line, which can be adhered to the RFID card. The email can later be reread by laying it on the command reader, which will open the email client and display the message.

4.3 Managing Email Filtering

In addition to insuring a manageable number of incoming emails, the email filter is crucial to protecting the users from spam and email hoaxes — this is particularly important for the elderly, since they are targets of scams. The filter should be restrictive, but the syntax of the filter rules should be to permit a correspondent email address.

We expect that initially the filter will be managed by a system administrator, but eventually the older computer users will want to add permitted correspondents themselves. An "email filter" command card can display a short list of permitted correspondents, and list manipulation interaction techniques similar to receiving email can be used to move through the list, view details of the correspondents, and delete correspondents from the permitted list. Adding a new correspondent to the permitted list is a bit problematic without typing and understanding the syntax of email addresses. But in some cases typing the email address can be avoided by the exchange of email address cards. Users of the RFID email client can make "email address" cards and exchange them. The new address can be added to the permit list by laying both the "permit" command card and email address card on the reader.

We do not presume that the above description is a complete interaction design specification. Our intent is to give a detail example of RFID cards interaction techniques in context, and to illustrate that the laying of cards can replace many selections using a mouse. Earlier, we proposed that older computer users should not be enslaved by the new technology; the interface should permit more skilled users to make selections with the mouse. All the text in the graphical interface can double as text entry fields and/or buttons; consequently all the standard commands should appear as buttons in the interface. This way the older computer user can choose to interact using RFID cards or the keyboard and mouse.

5 Summary

Elderly adults in assisted living communities and especially those who are wheelchair-bound are deprived of much human contact. Increased social contact can improve both the moral and physical health of elderly adults. The computer offers several media for communication, notably email, chat and web browsing, with the greater society. Older computer users' favorite task on computers is communicating with family and friends using email. But older computer users face many barriers to computer use. Old age brings failing eyesight and decreased motor and cognitive skills, making it difficult to read small text on the monitor and select items with the mouse.

Our review of the TUI literature and categorization of RFID card interaction techniques illustrate that RFID tagged cards are a viable tangible interface device with a rich interaction technique. They can enable selection by laying RFID cards or more tangible interaction techniques such as manipulating lists. We believe that the description of an RFID card email client demonstrates an older computer user accessible UI, which eliminates many if not all mouse-clicks. It also illustrates advanced RFID interaction techniques in the context of a computer application with multiple and dependent interactions. The RFID card email client also illustrates an interface metaphor that makes use of limited functionality and a graphical interface that has sufficient monitor space for large fonts.

The results of our designs can be generalized to other user contexts. For example, the TUI card system does not have to replace mouse pointing. Rather, the RFID cards can be used in conjunction with the mouse. We expect that TUI techniques can be tailored to a wide range of computer users. For example, business cards might be equipped with RFID labels so that an exchanged business card can open a web browser to the new acquaintance's website.

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