Natural Gestures For Active Reading Behaviors

Matthew Hong
University of California,
San Diego
m1hong@ucsd.edu

Neema Mahdavi
University of California,
San Diego
mahdavi@ucsd.edu

ABSTRACT
Our research draws a vision that showcases various types of natural interaction techniques that altogether support active reading. Informed by observations of active reading behaviors and exploring possible interactions through paper, we were able to gauge the extent to which technology should pervade our active reading experience. We make two important contributions to HCI research: first, we explore the problem space of traditional desktop workspace interaction and lay the foundational framework to inspire design that is grounded in natural active reading behaviors; second, we provide implications for designing future interactive workspaces and a video prototype to present a concrete visualization of our vision.

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Tabletop computing, paper, document manipulation

ACM Classification Keywords
Design, Human Factors,

INTRODUCTION
Although information technology continues to evolve at a rapid pace, the current computing paradigm faces a fundamental challenge. There exists a narrow interaction bottleneck between the input medium and the diverse range of applications it upholds: 1) the present desktop computing paradigm still relies on a keyboard and mouse oriented input device; 2) tablet devices allow for either pen-based (e.g. Wacom) or multitouch input (e.g. iPad). As a consequence, the combined use of such unimodal input devices introduce new breakpoints (i.e. explicit modality switch) rather than improvements to the workflow and overall user experience. In an effort to broaden this interaction bottleneck, previous studies draw upon observational data to explore novel interaction techniques on the surface.

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However, it is difficult to find common ground among the multitude of suggested interaction techniques as they are often extracted and adopted to fit within the context of surface technology. Based on our observations of desktop reading activities and exploration of possible interactions through paper, we provide implications for designing future interactive workspaces, and a video prototype to present a concrete vision.

RELATED WORK
In this section, we review prior research efforts that also address the central concerns of the problem space we investigate. First, we begin with a literature review of behavioral models from experimental psychology that lay the foundations for human computer interaction. Next, we survey previous studies in HCI that adopt these models and analyze their consequences. Finally, we look at past and recent work on Active Reading, which sets the context for our paper.

Descriptive models of manual behaviors
The left hand knows what the right hand is planning, and the right hand knows what the left hand just did.

—Frank R. Wilson [29, p. 160]

One of the earliest documentations of manual behavior includes John Napier's [19] description of prehensile movements, of which an object is held by a gripping or pinching action between the digits and the palm. Before Napier famously proposed the classification of two prehensile grips (i.e., power vs. precision), he observed that, "during a purposive prehensile action, the posture of the hand bears a constant relationship to the nature of that activity". In our analysis of active reading activities, we observe unique prehensile actions that are consistent with Napier's description, especially regarding the use of pen.

Guiard [8] investigated the differential roles of preferred and nonpreferred hand in a shared task. Of particular interest is his justification of writing (previously conceived of as a unimanual one) as a bimanual task, showing how the non- dominant hand performs a complementary role of continuously repositioning the paper with respect to the motion of the writing hand. Based on his observation of a range of bimanual activities (such as writing, drawing, and sewing), Guiard concluded that "there is a logical division of labor be- tween both hands that appears to govern the entire range of human bimanual activities," of which the non-preferred hand both precedes and sets the spatial context for the activity of the preferred hand – hence the kinematic chain model [8]. Most of our observed activities consist of asymmetric bimanual movements and have been described within this frame- work.

Both Napier and Guiard's models of manual behavior (see [29] for review) share a common characteristic property, of which the movement of one's hand occurs in anticipation of the nature of its activity. This notion runs parallel to how humans interact in the context of face-to-face conversations, in which the hand movement or conversational gesture tends to pre- cede the semantically-linked utterance of speech [5, 13, 18]. Nonetheless, the tight relevance between the two domains of psychology is worthy of attention since gestures also serve an important role in the realm of HCI as a way in which humans communicate with computers.

Informing HCI design

Around the same time Guiard proposed his kinematic chain model, Buxton and Myers [6] were first to explore the efficacy of two handed input in computers. Their study involved a simple experiment that compares unimanual with bimanual input, concluding that two-handed input readily outperforms the former. Although independent of Guiard's work, and providing little insight into the differential roles of both hands, their research brought increased awareness to studying bimanual input mechanisms on computers.

The marriage between experimental psychology and human- computer interaction disciplines began when Bier [3] and Kabbash et al. [12], took guidance from Guiard's work to inform the conception of the Toolglass metaphor – a semi- transparent palette-like interface that was controlled by the simultaneous but functionally asymmetric input from two hands. As Guiard's model of bimanual skilled interaction seems to serve an important role in informing human to computer interactions grounded in natural bimanual activities, subsequent studies in the HCI discipline still continue to cite his work.

Mode switching, is one topic of research that has benefitted most from this interdisciplinary merge. The need to switch between different mode states in graphical user interfaces has been addressed by Shneiderman's Object-Action Interface (OAI) model [24], of which the user is obliged to select an object first and then select the action to be performed on the selected object, and vice versa. In an effort to over- come this interaction bottleneck, previous studies have explored a multitude of pen and touch based interactions by virtue of learning from naturally occurring interaction techniques. Inspired by Napier's account of prehensile actions

and certain grip postures used by artists, Song et al. [25] explores mode switching techniques that incorporate the use of various grip postures and multitouch gestures on the surface of a pen. Inspired by the way artists manipulate a conté crayon, Vogel [28] explores mode switching techniques that leverage the various contact points of an interactive prism- shaped crayon and its interaction with the multitouch table.

Two-handed mode switching techniques have been explored extensively, especially involving the combinatory use of pen and touch interactions. Li et al. [14] conducted an experi- mental analysis of five different mode switching techniques for pen-based user interfaces and concluded that pressing a button with the non-preferred hand yields the best perfor- mance in terms of speed, accuracy, and user preference. This study stimulated a body of research [?] that further con- firmed the importance of understanding bimanual interaction and the asymmetric division of labor among both hands to switch between different mode states. Brandl [4] describes several examples of bimanual pen plus multitouch gestures, assigning pen to the preferred hand and multitouch to the non-preferred hand. Seeing the limitations of the previous study, Hinckley [11] explored a wider vocabulary of pen + touch techniques that considers the interleaving assignment of pen and touch manipulation to either hand, depending on the usage context. Inspired by the Toolglass metaphor and the affordances [23] of physical paper, Song [26] looked at bimanual interaction techniques that render the nonpreferred hand as a frame of reference by controlling the visual feed- back projected onto an Anoto patterned paper. As of today, simultaneous pen + touch interactions still govern a large portion of HCI research that considers the division and al- location of task assignment among both hands.

Alas, the current direct manipulation paradigm introduces breakpoints to the optimal work experience of the user. Often referred to as "staying in the flow" or the flow [7] experience, in the field of psychology, Bederson [2] asserts that the flow experience in human-computer interaction may be subject to interruptions when visual feedback (and the attention thereof) becomes a requirement for task execution. The difference between pressing the keyboard shortcut Ctrl+C and having to trigger a contextual menu in order to locate and execute the copy command illustrates this problem very well. In fact, the reciprocity between visual attention and the cognitive cost for switching between subtasks has been discussed in light of Guiard's theory of bimanual interaction. Exploring bimanual vs. unimanual interactions on the "doll's head" neurosurgical interface, Hinckley [10] saw the cognitive benefits of two-handed manipulation whereby the use of both hands, afforded by the tangibility of the interface, al- lowed for the decentralization of attentional resources such that a low transaction cost for switching between sub-tasks was made possible.

Active Reading

Our work looks at natural pen and paper based interactions in the context of Active Reading, which is a common activity observed among people who engage in knowledge work [1]. Active reading is a form of knowledge consumption that requires a high level of interconnectivity among reading-

related tasks to retain the "flow experience" of the reader. Such activity is characterized by the fluidic transitions be- tween immersive reading (the primary task) and a set of sub- tasks that are collectively in support of the active reading experience. These secondary tasks support information consumption by means of casual information creation and organization activities, including annotation [17], content brows- ing [20], file organization [16], and cross-referencing [21] between multiple source documents. Due to the interlacing nature of interactions it sustains, active reading can serve as an important testbed for exploring interaction techniques that are cognitively less demanding.

Prior studies have attempted to support the active reading experience by modeling paper documents with digital technology. Motivated by the limitations of current ebook readers and tablet computers, XLibris [22] and PapierCraft [15] explored pen based gestural interactions by simulating a paper- like experience on a tablet display. LiquidText [27] explored bimanual multitouch interactions on a tablet PC along with flexible visual representations to recreate experiences that were previously unique to physical paper, such as viewing two disparate areas of text in a single pane. GatherReader [9] describes a bimanual pen+touch system that supports fluid interleaving interactions between reading and writing with- out requiring explicit specification or organization of content.

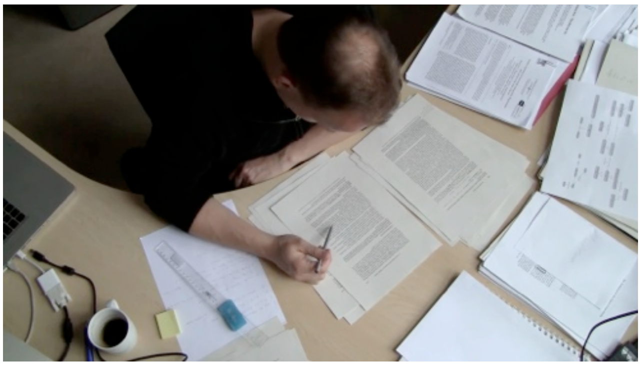
Still, the tangibility and materiality of paper outweigh the benefits afforded by computers, such that simply mimicking key affordances of paper will not suffice within the confines of software and hardware. Moreover, the role of technology should not be to replace some of the interactions that we are adept. When, where and how technology should pervade a cognitively rich activity such as active reading will always be a central question that we ask, and we explore it through this paper.

OBSERVATIONS

Our previous observational study on active reading behaviors has highlighted the major contextual cues that lay out the foundation for our iterative design process. Following is a summary of observations of active reading tasks that have provided valuable insight into our prototype design.

Skimming

From a state of immersive reading, active reading starts with skimming. A typical skimming activity is performed with a pen (and sometimes finger) hovering above the text in a linear fashion. The grip posture is fairly relaxed, the tip of the pen meets the surface at a slant angle, and is elongated enough such that it is visible at any orientation.



As a consequence, the pen tip serves as a transient focal point of the readers' attention. Since skimming and annotating both involve the use of pen, the transition is seamless between the two activities.

Place Marking

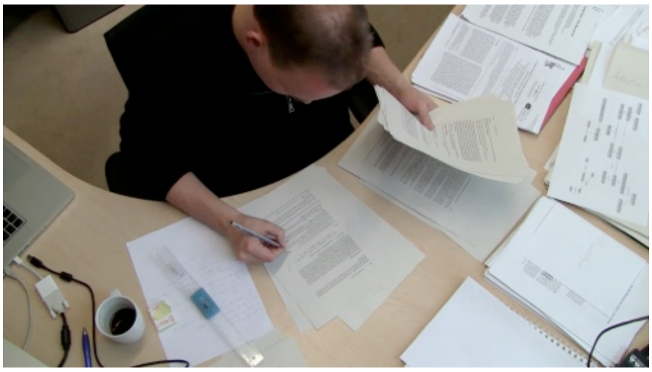
Skimming and annotating is often accompanied by marking. A marking gesture is performed with an index finger of the non-preferred hand, which is placed adjacent to an area of text that is being read. This gesture serves as a less transient focal point of the readers' attention and moves along the side margins of the text in a vertical manner.

Annotating

All annotating activities, including writing, underlining and highlighting, involve the asymmetric division of labor between both hands, of which the dominant hand writes and the non-dominant hand controls the position and orientation of the paper.

Different types of annotations afford different purposes. Short notes are written on Post-It notes or margins of the source document relative to the location of content they are linked. These notes serve as a permanent visual marker to direct attention towards the area of text most associated with them. On the other hand, underlining and highlighting provide salient markers within the text and takes advantage of the context to direct attention.

Cross-referencing



A hold gesture presents as a dominant cue when cross-referencing between multiple source documents. For instance, holding a paper in mid-air while reading from another paper on the desk is a clear indication that the reader has an interest in both papers and plans to return to reading the other.

Document Organization

Groups of paper documents are often organized into piles. Some piles may represent a distinct category of papers, while others are ephemeral in nature and their contents are readily subject to change. A stacking or chopping gesture is a great predictor of pile formation. The gesture has a profound presence in many organizational activities, also occurring when adding or removing papers from a pile.

Search/Browsing

Because papers and documents are organized into piles and stacked on top of each other, searching and browsing content becomes a serial and time consuming process. A within-pile search is typically performed by removing one paper at a time, beginning from the top of a pile. Performing a within-document search is accomplished in a similar manner by flipping through multiple pages in a sequential order. At the page level, a fine-grained search is accompanied by a hold gesture, which is reminiscent of the aforementioned cross-referencing activity.

DESIGN STUDY WITH PAPER

Paper Prototype

We created a general prototype of our system to act as a vehicle of our design ideas. To help with our brainstorming and give form to our thoughts, we created a paper prototype that would be representative of our system. Using paper as our GUI menu, we created a stop-motion video through the use of photography. We tried multiple configurations of the paper prototype, but only made one video to provide the means to reflect on our design. Although our design ideas were not clearly and completely thought out, we saw prototyping as a way to be able to visualize our thoughts and be able to tackle the issues of our design step-by-step after.

Graphical User Interface

Our graphical interface contained three different buttons that acted as mode-switchers. These three elements were "save," "edit," and "annotate." At the time of inception, we were not able to create a better way switch between modes and a graphical interface was our temporary solution.

Activation

The early version of the system that we prototyped would be activated by the user placing his nondominant hand on the paper. We were first motivated by the domineering presence of the nondominant hand and how involved it is in annotating tasks. Thus, the system would be largely influenced by the spatial framework provided by the nondominant hand. For example, non-dominant hand placement on the paper triggered a graphical user interface, with the three above-mentioned buttons appearing in a vertical fashion to the right of the user's document.

Skimming & Annotation

By pressing 'edit' on the menu, the reader would be able to underline and skim the document using a pen. Afterwards they would save their state by pressing 'save.'

To access their annotations they would press the 'annotate' button which would bring up the previously highlighted passages or written annotations on the page. Skimming their fingers across text in this mode would highlight the word that they were hovering above.

Pile Creation

The chopping gesture that reader makes to create a pile activates the new stack recognition of the system. The user is then given visual feedback of the new stack which is displayed directly underneath the stack. Stacks are unnamed, similar to when a new folder is made on a computer, the operating system simply names it as a "new folder." This was chosen because users did not name their stacks naturally and it would add confusion if they were not able to see the stack's name or search for a specific stack.

Select and Send

To select a portion of text to send to an external device, the reader would use one finger and drag it diagonally across the paragraph. When the reader lifts his finger from the portion of text, it is selected and outlined by the system. The reader then uses one finger to drag the selection from the paper onto an external device, such as a phone.

Results & Iteration

At the time, we believed that our system had to be physically turned on and the user needed to be notified that the system was operating.

Through this prototype we were able to see problems with our design, the interaction techniques, and the interface as a whole. We found that the system was constrained by its existence and some overlapping gestures. We storyboarded the entire system all over again, concentrating on how to switch modes based using the pen instead of a graphical interface. We learned that it is important not to change the make active reading into a new activity by introducing a learning curve. Through revisioning we found that our paper prototype was trying to replace any physical means of annotation activities into digital representations.

Final Prototype Design

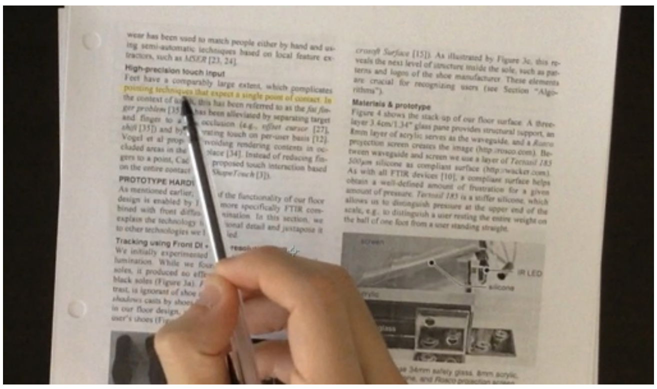
After refinement and discussion of the paper prototype and several storyboarding sessions, we were able to finalize our design.

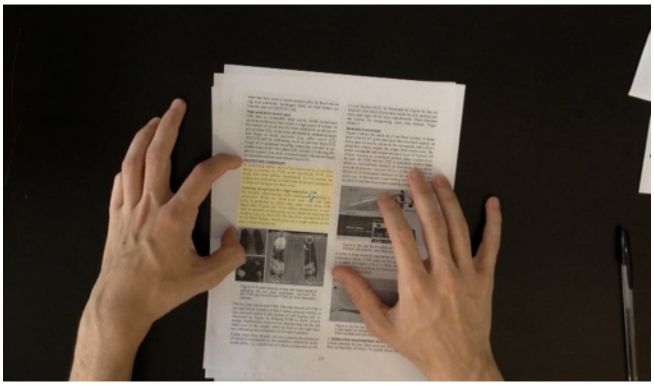
Activation

We modified the systems activating cue; instead of making a gesture to turn the system on, an increased change in weight on the chair would activate the system. Contrary to our prototyped designs, we decided on no visual feedback for the system being on. By not explicitly telling the user there is a system to even turn on, it further supported the use of natural gestures and helped us create a natural environment.

Skimming

To support this activity the system casts a focused high-intensity light on the entire line which the word appears. The line enters this focused mode when the tip of the pen or finger meets the text on the paper. The focus is only temporary, it fades away as the reader moves his pen or finger away from that line and the focused light follows. This provides a supplementary visual cue to guide our attention. Previously the pen only allowed a very specific focused view by concentrating only on a word. However with this system the reader is now able to focus on entire lines.





Pinch-to-select

Similar to the "pinch-to-zoom" gesture on mobile phones, a pinch gesture using the index finger and the thumb is made alongside a section of text is made to highlight and select that portion. This is used to either mark the place of the reader while they work elsewhere, or to use in other features of the system, such as copying and transferring.

Copying & Transferring

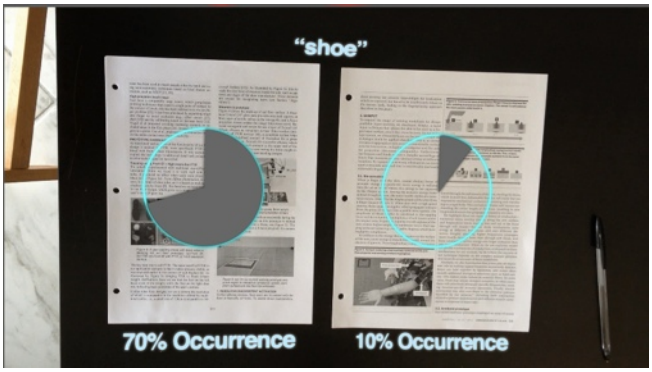
Using two fingers, unlike the previous iteration with one finger, dragging a selected area into a designated area off of the document close to the edge of the table sends the selected portion to the users email or mobile device. By using two fingers, we are preventing an overlap of gestures in the system. Flicking an image with one finger would send the image to the closest external monitor in the direction of the flicking motion.

Pile Creation

To support organizational activities, a user may create a stack of papers that the system would be able to identify by making a chopping gesture with the pile. The chopping gesture is not recognized by the camera, but rather the acoustical feedback it provides is picked up by microphones. After the sound is recognized by the system, the camera recognizes the pile and creates a digital stack, giving visual feedback to the user that a new stack has been created.

Searching within a stack

However to search within the stacks, the search gesture was not implemented. To reduce the number of false positives and errors of the system, we created a multimodal searching system. The search gesture was used in other contexts, even when searching was not the activity at hand, so to be certain that the gesture wouldn't overlap we turned



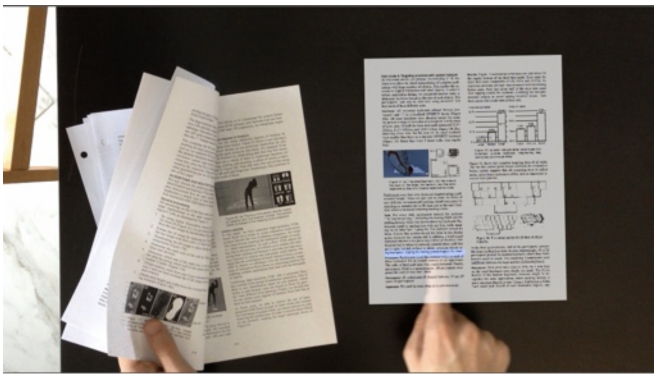
to an auditory solution. There is no way for our system to flip through pages and show direct instances of the keyword, instead the system stores images of each page of the document and when searching through each stack, recalls those images and by using OCR software recognizes the occurrences of each word then notes the number of keywords. After this process, the system shows a visualization of the percentage of occurrences of the keyword in the stack and highlights the keywords as the reader flips through the pages. This may be used as a standalone single stack search, or a comparison between stacks.

Parallel View

Parallel view is activated when the user is comparing two pages in a single stack using the cross reference gesture going back and forth between pages. After 2 to 3 flips, the page that is tucked in between the reader's fingers is recognized by the system and a duplicate is projected onto the desk, such that the user may interact with both pages in parallel without having to flip back and forth.

Annotation

The annotation feature was revised and the characteristics shown in the paper prototype were removed. To ensure annotations would be available when the user was not in front of the desk, we were required to use real ink instead of digital ink. The system still recognizes that the user is annotating and is able to capture the annotations using high-definition cameras.



EVALUATIONS

When, where, and how digital technology should pervade our active reading experience is a central research question we ask and explore through this paper. We learned from our initial paper prototype study that there needs to be a profound understanding of the nature of active reading activities in order to conceive of a cohesive system that does not force the reader to conform to a mental model uncommon to the reader's experience. We first approach this problem by understanding the degree of complexity and richness of the activities, which also amounts to the degree of cognitive effort required by the reader while engaging in an active reading session.

Cognitive framework

There are three levels or layers of activity spaces that we believe are representative of the extent of cognitive resources to which the reader needs to allocate.

The first (core) layer consists of the central task of active reading -- immersive reading. This state of reading requires an intense level of concentration and may be susceptible to the slightest of interruptions. Writing is yet another task of equal importance. In the context of active reading, writing is a common by-product of immersive reading and a result of deep contemplation and reflection upon said reading. The second layer embodies several peripheral tasks that are in direct support of these activities. Such tasks include, skimming, underlining and highlighting, and cross-referencing between multiple source documents. The third and last layer consists of small tasks that are least demanding of cognitive effort, which include content browsing and document organization. The farther we move away from the core layer, the more cognitive effort is off-loaded to the movement of our hands. What we aim to support then, are the peripheral activity layers that engage the use of our hands that are often automatic and implicit reactions to the immediate context.

Choosing which activities to support

We believe it is best not to replace existing practices of active reading that we have cherished for so long. Instead, we want to support them at the right place and time by filling the gaps and holes with the affordances of digital technology. Thus, we classify active reading activity into two distinct groups: one that is to be recognized by the system and the other that will be reacting to the reader's behaviors.

As mentioned above, the core layer tasks -- reading and writing -- are the most cognitively demanding, and vulnerable to interruptions such that they must not be intervened by digital technology. However, digital technology may still intervene at a subtle level for purposes of recognizing reader activity. Document organization, although not a core task, has been assigned to this category because of its relatively short-lived interaction span.

On the other hand, the best use of technology will be to actively support skimming, cross-referencing and searching activities, which are very much dependent on the visual cues provided by place-marking gestures or the tip of the pen. These cues can be digitally enhanced with visual feedback.

Mode switching

Several observations promise room for implicit mode switching. For instance, skimming and annotating activities both share a common artifact; they both involve the use of pens. Although the postures may differ (i.e. relaxed vs. tripod grip), if used on the same pen, these differing configurations may be used to switch between writing and skimming.

Many other activities center around two gestures: place-marking and holding. These gestures provide a spatial frame of reference that guide our attention to facilitate the aforementioned peripheral activities (e.g. skimming, cross-referencing, and searching). For instance, skimming and cross-referencing are accompanied by a place-marking gesture while cross-referencing and searching is accompanied by a place-holding gesture. Such gestures may render them useful as a mode switcher for the associated activities.

Mulitimodality

Certain physical properties exhibited by the gestures promise an alternative input channel that may foster human-computer interaction. For instance, the stacking gesture that is used in piling activities embodies a unique acoustic property. When a bundle of papers hit a flat surface, they generate an acoustic pulse pattern that is distinguishable from other activities. Flipping multiple pages and searching through a pile of documents also generate unique range of frequency amplitudes that are afforded by the physical materiality of papers and the quality of interaction thereof. As long as the computer can pick up and identify these actions by the peculiar range of acoustic signals, there is hope for multimodal integration.

DISCUSSION AND CONCLUSION

In conclusion, we draw a vision that showcases various types of natural interaction techniques that altogether support active reading. Informed by observations of active reading behaviors and exploring possible interactions through paper, we were able to gauge the extent to which technology should pervade our active reading experience. We make two important contributions to HCI research: first, we explore the problem space of traditional desktop workspace interaction and lay the foundational framework to inspire design that is grounded in natural active reading behaviors; second, we provide implications for designing future interactive workspaces and a video prototype to present a concrete visualization of our vision.

Since this is a fairly new approach to technologically-assisted active reading, the technology that would be necessary to create this system has not been fully developed yet. We believe that within two to five years until there will be enough advancements in gesture recognition hardware and software (such as Leap Motion's gesture controller) so that we will be at a point where a system such as ours will be able to be implemented. With the current rapid advancement of OCR software in combination with the progression of higher definition cameras, this system would be able to take form within this timeline. Our system is to support technology being built around on natural behaviors instead of asking for the user to learn the technology. This would provide for a more natural experience. We also hope that our work inspires more research to be done in the field of ubiquitous computing and linking the digital and physical worlds, without a need for supplementary digitalization of the objects with QR codes. Our future research will involve also analyzing and expanding more activities in this system.

In the future we hope to create a Wizard of Oz prototype of this system to test the capabilities of our system with real users. This user research may perhaps show behaviors that may have been overlooked in our data collection stage.

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