Enhanced Digital Visualization of Paper-Based Notes for Efficient Review

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Taking notes has been found to be beneficial, especially in terms of note review at later dates. Though notes have been traditionally taken in paper notebooks, digital capabilities have recently emerged. However, both techniques alone have disadvantages that limit the note-taker, particularly in reviewing notes after they are taken.

The Anoto collection of digital pens provides a way for paper-based notes to be captured and transmitted to digital devices, allowing users to access their note digitally. Pen strokes on special paper are captured via a matrix of dots on the paper and an infrared camera in the pen; the exact location of the pen is recorded, and the strokes are converted to digital copies of the notes. Despite the accessibility that this affords, the implementation lacks more advanced forms of exploration, search, and reorganization.

Several projects have been built to enhance the functionality of the Anoto pens. For the most part, these projects concern interaction at the paper interface, and less work has been done with the digital interface and note visualization.

Overall, the area of digital pen technology is still in a relatively early stage. Though research has been conducted and several projects have been developed, digital pens have yet to catch on in the general public.

This proposal outlines some of the outstanding issues that exist with digital pen technology – particularly the difficulties and inefficiencies of subsequent visualization and review. While traditional means of note review should be preserved, a digital visualization system should offer significant advantages over paper-based visualization to make the process of note review far more efficient and valuable.

Here, such a visualization system is proposed. The system will be based off user research and existing literature, which will be leveraged to determine the interactions that need to be supported. So far, user interviews and notebook analyses have been conducted and have revealed a number of important trends. Further research will continue to inform the design of the system. When enough user data has been collected and a functioning prototype has been created, development of a full tool will begin.

The intellectual merit of this project arises from the knowledge that will be gained about how a variety of people take and review notes. In addition to informing the design of this system, such data could provide insight into the types of note-taking techniques and elements that lead to higher performance. The broader impact is that the tool would enable better note integration and accessibility, which could help a variety of professions that rely on information from notes. This could also allow people to see information or trends that would otherwise be hidden by poor visualization.

Key words: note-taking, digital pens, human-computer interaction, information visualization, notes

1   Introduction

Paper and ink have long been the traditional medium for manually recording ideas, taking notes, and communicating asynchronously. Despite the strength of the human mind and memory, creating physical records of thoughts works to serve as a more permanent and accurate representation of a fleeting thought.

1.1   Reported Goals of Note-Taking

The prevalence and continued practice of note-taking is undoubtedly a testament to its central role in many people's daily lives. Several studies have shown that between 90% and 99% of students in traditional lecture classes take some form of notes (Palmatier et al., 1974; Abowd, 1999; Steimle et al., 2007). For student attending lectures, research has found at least three primary beliefs and motivations for note-taking: (1) that notes will be useful at a later date to review information that was presented at the time of the note-taking; (2) that the act of taking notes itself will effect better cognitive processing and help solidify the information into long-term memory; and (3) that the act of note-taking aids in concentration during the session (Hartley et al., 1974).

Later research has shown that non-students tend to rely on notes for the same purposes. Some information workers stated that their primary use writing notes was to better "[fix] the information in their memory," while others described notes as a means to remember details that might otherwise be forgotten (Ispas et al., 2010). It's reasonable to assume that these motivations extend into other professional and recreational domains.

All three of the above discovered motivations have significant value for future research on the cognition of note-taking; however, the proposed research focuses primarily on the use of notes as a way to recall information at a later date.

For people that use notes as a means of storing information for future review, effective note-taking inherently relies heavily on one's ability to access and make sense of their notes; the ability to correctly access and interpret one's notes in turn depends on the efficiency of note-capturing at the time the note was taken. We can also frame the idea of note-taking as a means of communicating with the future self in a way that yields more effective results than relying on memory alone.

1.2   Theories on the Value of Note-Taking

As discussed above, a common theme of note-taking is the goal of leaving a more permanent reminder of something that needs to be remembered in the future. Norman describes a dichotomy wherein memory consists both of knowledge in the head and of knowledge in the world (Norman, 1998). Creation of knowledge in the world serves to supplement, reinforce, and preserve knowledge in the head, which is often prone to distortions and forgetting. According to Norman, a successful reminder (e.g. a memory aid) consists of both perceptual salience and the message or content to be remembered. Though Norman himself claims that a note contains only the message aspect of a reminder (Norman, 1998), it's also reasonable to state that its physical presence on a page makes a note salient to a certain degree. Either way, a note's role as a reminder to at least some degree is generally accepted.

Clark has proposed a controversial theory – "Extended Cognition" – stating that the mind extends beyond the biological form of an organism and out into the environment and objects with which the organism interacts. With his theory, he further advocates the use of notes as memory. He describes Otto, a hypothetical man with Alzheimer's Disease who, as a result of his memory deficits, relies on a paper notebook to record his thoughts, reminders, and information.

This notebook becomes an extension of his mind because it serves as his extended memory. Clark compares Otto to a woman with a normally-functioning memory. Before consulting their respective memory devices (Otto's notebook and the woman's internal memory), each knows that they have the information available. The only significant difference is the location of the information (Clark, 2008). Through this thought experiment, he claims that the same cognitive result is

achieved and therefore Otto's notebook must be part of his cognition. Clark uses the example of a man with Alzheimer's, but this phenomenon applies to each of us every day. According to Clark's Extended Mind hypothesis and the related concept of embedded cognition, our cognitive boundaries either extend to or are manifested via the tools we use to inform and make decisions (Clark, 2008).

Thus, jotting down a quick note is a way to give our thoughts more permanence, and being able to do this as quickly as possible reduces the cognitive bottleneck involved in transforming these thoughts into a new representation (Hutchins, 1995).

1.3   Observed Benefits of Note-Taking

Several experimental studies have investigated the realized benefits of note-taking in everyday life with respect to the above theories. A review of note-taking literature shows that note-taking and the subsequent review of notes produces better recall performance that no note-taking at all or note-taking without review (Carter et al., 1975; Fisher et al., 1973; Rickard et al., 1978).

Additional studies have shown that although both the process and product of note-taking (i.e. writing the notes and reviewing them later, respectively) are valuable, the review of notes has more of an effect on achievement than the process (Kiewra, 1987). These results suggest that the degree to which notes can be effectively visualized plays an important role in activities that rely on knowing the information contained in the note.

1.4   Paper vs. Digital

Research has shown that paper is by far the most common medium for quickly capturing notes (Steimle et al., 2007). A comparison of paper and digital notes, as well as an introduction to digital pen technology, is discussed below.

1.4.1   Paper Notes

Paper-based annotations offer myriad advantages over other forms, such as digital (Liao et al. 2007).

Importantly, paper is cheap, portable, accessible, ubiquitous, and familiar. Ease of use is vital to efficiently capturing thoughts. Paper also has the advantage of immediate temporal and spatial feedback; when one writes or draws on a piece of paper, the effects are seen instantly and in the exact place they were made. This provides a more direct expression of the intricacies and precision of human fine motor control, rather than relying on a digital interface to interpret and reformulate our actions (e.g. typing). Individual pages of paper are also able to be "laid out in physical space for comparing and organizing pages and documents" (Sellen et al., 2003), which may afford cognitive advantages (Kirsh, 1995).

Recent field data found that students prefer to take notes during lectures using traditional paper rather than electronic tools, such as a laptop. Reasons for this preference include the ability to produce handwritten notes and sketches (Steimle et al. 2007). A part of this proposed research is to further investigate the types of notes people take exclusively by hand in order to inform decisions for future design; some preliminary research has already been conducted and will be discussed later.

However, paper is not without its disadvantages. Its permanence confines it to exist in a single location, both in that an annotation is stuck on a single page and stuck in a specific place on that page. For example, this makes it difficult to reorganize bound notebooks; to group notes that are spread out across multiple pages; and to separate two unrelated sections of notes that were taken on the same page. Efforts to overcome these restrictions, such as photocopying, scanning, or cutting and pasting, are inefficient and can degrade the quality of the note over time. Even with these solutions, there is a significant time delay before copies of the document can be shared or interacted with.

1.4.2   Digital Notes

With increasing frequency, digital devices, such as desktop computers, laptops, netbooks, and mobile smartphones, are being used to create and share documents that are highly interactive and editable. Digital notes offer several advantages over paper. One of the most important advantages is that the same digital doc-

ument can easily exist in more than one location at a time and can be quickly moved from one location to another. For example, tagging a document with multiple tags allows it to be accessed from multiple paths, while a single paper document cannot simultaneously exist in two physical folders. At a higher level, digital documents allow robust reorganization abilities as they are not spatially fixed upon creation.

While searching through paper notes is generally confined to visual scanning across pages of notes, digital storage permits content, categorical, and contextual search. Though paper note-takers sometimes use non-content visual markers (Ispas et al., 2010) to demarcate sections of their notes a la Norman's concept of a reminder's salience (Norman 1998), visual inspection of a page requires at least some level of cognitive processing (e.g. reading, deciphering symbols, etc.). Digital note-taking affords various tasks to facilitate future search-based retrieval, such as assigning categorical labels to sections of notes.

Cloud services allow for even better access to digital files. As computers become more ubiquitous, it becomes increasingly difficult to manage files across multiple devices. Services like Dropbox, Evernote, and SugarSync offer services that will synchronize files or notes across any device with the applicable software installed. While one needs to carry a paper notebook with them at all times if they want universal access, cloud technology enables digital access anywhere without needing to carry anything around.

Still, while digital management is much more robust than trying to organize paper notes, digital technology lacks sufficient input devices for the degree of fidelity and ease people expect when seeking an alternative to paper. Graphical tablets are expensive and cumbersome, and only the high-end stylus input devices contain screens, so there is still usually a disconnect between the pen position and where the input appears (i.e. a lack of visual feedback). Thus, it is difficult to capture anything besides typed text on a digital device, especially in real-time.

Digital notes also lack a method for freely structuring the notes on a page; researchers note that paper notes "contain mixed cursive and printed writing, often written at angles, in various sizes, and at various locations all over the page" (Shilman et al., 2003), potentially a further testament to Kirsh's idea of enhanced cognition through spatial arrangement (Kirsh, 1995).

1.4.3 Digital Pen Technology

Much research and development time has gone into creating digital pen tools that can capture note and sketches on physical paper, combining the advantages of both digital and physical systems. One of the primary technologies is provided by the Anoto Group AB. The Anoto system uses a pen with a small camera pointed at the writing tip and a printed pattern of dots unique to each piece of paper. The camera reads the series of dots located beneath the tip as the user writes. The fine pattern of dots allows the camera to capture not only the location of the pen on the current page, but the individual identity of the page as well. The pen stores this data, and when the user connects the pen to their computer, the data is synchronized with the Anoto software to create a digital copy of every pen stroke made on the Anoto paper.
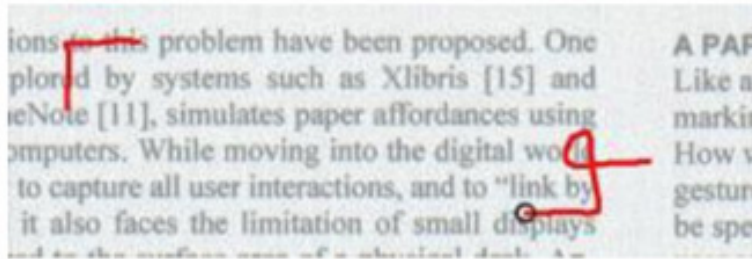
The basic Anoto implementation allows users to view a digital copy of the pages of their notebook, but the ability to restructure and reorganize digital copies, especially via the paper interface, is thus far lacking.

1.5 Related Projects

Several projects have been envisioned and created to expand upon the basic functionality of the Anoto pens, though most focus primarily on the interaction design of the paper interface rather than the subsequent digital visualization.

1.5.1 PADD

An 2003 paper introduces an early exploration of the physical and digital interface via Paper Augmented Digital Documents (PADDs). The PADD application allows users to annotate printed documents via either the paper interface (with a digital pen) or the digital interface. PADD was one of the first

Figure 1: PapierCraft gestures for copying (left) and pasting (right) via the paper interface.

systems to treat these digitally-enhanced notes as existing equally as paper and digital. However, the authors conceded that at the time, paper offered navigational advantages in that it could more easily be manipulated and that multiple pages could be spread out to better visualize information (Guimbretièr, 2003).

1.5.2 PapierCraft

PapierCraft introduced a stroke-based gesture system that allowed explicit manipulation of notes via the paper interface. After conducting a series of pre-defined gestures (figure 1), users could synchronize their pen to see the gestures manifested as commands to modify the documents. Several visualization techniques were introduced, including ways to explicitly link notes together and searching via tags. Through user testing, the researchers found the lack of visual feedback to be problematic (Liao et al., 2007), but it was a step in the right direction for interaction at the paper interface.

1.5.3 CoScribe

The CoScribe project included more techniques for annotating and managing documents. One important technique was the ability to create links on the paper interface: a user could touch a portion of the page and the corresponding digital document would be opened (Steimle et al., 2009). This interaction method could allow for navigation via paper notebooks but visualization of annotations in the corresponding digital notes.

2 HIGH-LEVEL VISION

The primary goal of the proposed project is to create a system that builds upon previous projects and affords more efficiency in the visualization of these digital notes. User research will help discover the most common visualization tasks and shortcomings to inform the design of a robust visualization system. Next, the system will be implemented and evaluated.

Outlined below is an idealized context scenario describing the behavior of a targeted user with respect to the goal above. The scenario describes the integration of the tool with his daily life and is followed by a discussion of to-be-supported tasks extracted from the story. Though the scenario involves interaction at the paper interface, the proposal will address the digital visualization of these notes.

2.1 Scenario of Use

Alex is a tech-savvy university student. He's also a part-time web designer and strives to balance his academic, professional, and social lives, making sure that he gets everything done on time while still having fun. He has a desktop computer and a smartphone, as well as a digital pen and a single notebook of digital-pen-enabled paper. He uses his digital pen for every note that he takes.

2.1.1 Class Notes

As a student, Alex attends lectures and takes extensive notes. In the past, he used separate notebooks for each class, but found himself wasting too much paper as he often never had enough notes to fill an entire notebook. He later tried allocating the right numbers of pages for each class at the beginning of the quarter, but found himself either over- or underestimating what he needed, leaving him either with extra pages or not enough.

Now he uses one notebook and doesn't bother to try to separate his class notes. He knows that he'll be able to compile all of his class notes in their respective folders, so it doesn't matter that he started his chemistry practice problems right below his history notes. He draws a line between the sets of notes and does a few simple commands by tapping on paper-based buttons, assigning each section to its appropriate class. When he logs onto his computer later that evening, he opens the digital folder for his chemistry class and sees his practice problems amongst the rest of his chemistry notes, completely devoid of his history notes he'd taken just a few lines higher on the paper page.

Alex realizes he has a math test coming up, and his professor allows a "cheat-sheet" – a single page of notes that can be brought to the exam; he usually brings a list of important equations to make sure he doesn't make a careless recall mistake. He launches his digital notebook manager and does a search for all notes tagged with both "MATH 20C" and "equations," and a full listing of all relevant notes is displayed. He clicks a button to compile all the notes onto one page, and prints the resulting page out.

He notices that he's forgotten an exponent on one of the equations, so he writes it on his printed sheet of equations. He's pleased when he immediately sees the addition on the digital copy.

2.1.2   Web Design Ideas

Alex likes to be able to write down ideas as they come to him because he knows how difficult it can be to remember ideas later in the day. In the past, he liked to flip to a specific section of his notebook because his ideas would get lost otherwise (if they were spread out throughout his notebook). He's familiar with the feeling of his ideas slipping away as quickly as they were incepted – a race between his search for the right page and the limits of his working memory.

So now, when he figures out an elegant way to solve a design problem he was struggling with, Alex lets his ideas flow onto the first page he opens to, which happens to be a page he used 3 months ago to sketch out the steps of a chemistry reaction. He uses a gesture to tag the new sketch and lines of notes as "design idea" and closes his notebook without even bookmarking the page.

When he goes on his PC later that evening, he does a quick search for the "design idea" tag and sees his most recent sketch at the beginning of the list. He can also easily access his other design ideas, including viewing multiple ideas at once to make comparisons – an activity that might otherwise be difficult if the sketches are spread out throughout a physical notebook.

2.1.3   Reminders and To-Do Lists

In order to manage his busy life, Alex creates to-do lists and reminders. While in class, he remembers that he needs to get the oil changed in his car and pick up some flowers for his girlfriend. He writes "oil change" and "flowers" in the margin of his class notes. He also taps a "to-do" button and draws a checkbox beside each item.

While doing some other errands a few days later, he opens the notebook manager on his smartphone and sees a notification saying that he has two incomplete tasks. Tapping the notification, he sees his handwritten notes beside digital checkboxes. He gets his oil changed and picks up some flowers, then taps the digital checkboxes to mark the tasks as complete.

In a similar fashion, Alex marks an acquaintance's email address with the label "reminder" with the intention of entering it into his contact book when he gets a chance. Like "to-do," this special label allows him to receive notifications when there are outstanding reminders. When he next logs in to his notebook manager, he sees his list of reminders right away, so he easily remembers to add his new friend's email address.

2.2   Tasks to be Supported

The scenario above describes a number of high-level tasks that the proposed system should support. Additional and low-level requirements will be determined through user interviews. Although a large portion of this scenario involves note capture techniques, this proposal primarily concerns visualization of captured notes, with the assumption that the notes are cap-

tured in a fashion that supports this visualization.

First, it should provide the ability to not only capture physical notes to create digital versions (as is currently implemented by Anoto), but should allow the user to mark different notes as belonging to different parent notebooks and support automatic filing in digital directories. This feature would allow users to keep their notes separate and organized without worrying about organizing the physical versions; the paper becomes more of an input device than a permanent storage device.

The system should also allow tagging of both full notes and smaller sections of notes. Tags should be able to be both raw (e.g. plain text, such as "equations") or smart (e.g. "to-do," which lends itself to notifications and digital interactivity). Importantly, tags must be easily searchable and visualizable in a digital environment. Though hand-writing recognition software has been used to convert these kinds of notes into digital, searchable text, its current unreliability (Steimle et al., 2009) suggests that an explicit labeling of notes with digitally-associated tags should be used. Such tags would be better suited for searchability because a user could rely on recognition (e.g. seeing a list of recent tags) as opposed to recall (e.g. remembering a specific phrase of text).

The system should, above all else, enable the user to effectively visualize the structure of their notes in a digital environment. This includes seeing the contents of individual notebooks, seeing a list of tags and the respective frequency of each tags, and being able to sort notes in an intelligent manner. The system should be simple and easy to use, yet robust enough to allow the user to find and view notes in powerful ways. The system should at least offer the same affordances as looking at the original note as it was written on paper, but should also incorporate complete support for a non-linear, dynamic structure.

3 Preliminary Research

Some early user-centered research has been conducted so far to gauge the value of such a system.

3.1 Methods

Though high-level tasks are ascertainable from the main goals of notes and existing research, it is desirable to gather data from real users of the target population. The proposed research targets users that need to keep a variety of notes organized and accessible, such as students with multiple classes and professionals balancing multiple projects. If subsequent research reveals dramatic differences between types of users, the study may need to become more focused on a particular group. For now, the expected result is that enough commonalities will be observed to justify a system that targets a range of users.

Therefore, initial research has targeted three drastically different users with the intent of finding both note-taking strategies and note-taking mechanisms.

3.1.1 User Interviews

Interviews with real users were conducted to provide a qualitative analysis of note-taking methods and styles. Participants were asked to bring current or recent notebooks that they used in everyday life. While some standard interview questions were used to provide the initial scaffolding for data collection, the interviews were driven primarily by responses to observed behaviors and comments by the participants.

3.1.2 Notebook Analyses

Structured analyses of participant notebooks were conducted following the initial interview. In some cases, it was improbable for some participants to be interviewed; in other cases, it was desirable to further investigate the elements of interview participants.

For a preliminary study, extensive exploration of every page of notes was impractical, so small, distinguishable sections were chosen for investigation. The analyses included documenting the various types of content and non-content notes that were taken and observing the frequency of each element.

3.2 Results of Early Studies

Though initial interviews have revealed a number of different strategies for note-taking, some common trends have been observed. Three case studies are

presented below.

3.2.1 Case Study 1: Undergraduate Student

The first participant described here is a third-year undergraduate student pursuing a joint Math/Economics major at the University of California, San Diego. Her ultimate self-reported goal for note-taking is to create a permanent bank of notes that she can review later.

She likes to keep each class in a separate notebook, or at least spread out across a single notebook. She notes that she has struggled to leave the right amount of space for each class, leading to unfilled notebooks or having to add extra loose leaf pages. She expressed a desire to try to conserve paper, but stated that her primary goal was to impose some kind of categorical organization, rather than linear, temporal organization. Similarly, if she starts her homework after a lecture, she leaves a few pages of space so that all her homework problems will be together and not alternate with lecture notes. In fact, she stated that on a few occasions, she has copied entire sections of notes to new areas so that that they were grouped with similar notes.

She likes to skip to a new page for each lecture, unless there is sufficient space on a page to allow a clear break between her previous and current notes. This is a testament to her desire to keep her notes visually separated and in distinguishable chunks.

She described a situation in which she went to office hours for a class and began doing practice problems after her lecture notes. Upon realizing that the problems were regretfully taking up valuable notebook space, she switched to loose leaf paper. She wished she could remove the first few practice problems from her notebook so that the flow of lecture notes wasn't interrupted and so that all of the problems were grouped together.

She also noted several meta-notes – non-content notes that served to highlight, emphasize, or give information about another note. Her techniques included underlining, highlighting, the use of different colors of ink, asterisks near information the professor noted to be important, and boxes around equations.
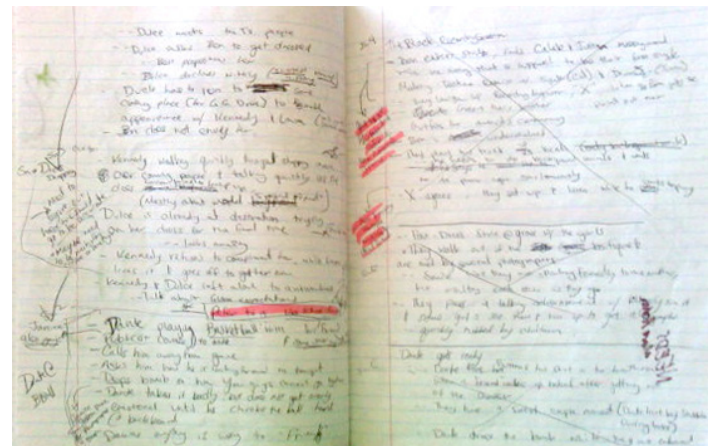
She expressed slight frustration with the difficulties she faced when searching through her notes, relying on visual recognition. She stated that knowing the approximate date of a note helped, as did the context of other notes.

3.2.2 Case Study 2: Screenplay Writer

The next participant is a recent university graduate, with a major in English: Creative Writing. He is currently pursuing a career as a screenwriter and has written and directed several short films.

In contrast to the student above, he makes little to no effort to keep different types of notes separated. His notebook is used primarily to capture ideas for future screenplays, as well as to formulate relatively structured scripts.

One of the challenges he faces is the speedy capture of spontaneous ideas that may be unrelated to

Figure 2: A two-page spread from the screenwriter's notebook. These pages show a number of elements, including: checkmarks, highlighting, crossing out, conceptual tags, meta-notes in the margins, and bracketing. This notebook shows significant clutter, and the participant expressed that it was sometimes difficult to find what he was looking for.

anything else currently in his notebook. Several pages are filled with single-line ideas that are semantically unrelated. He labels these ideas with their type: setting, character, plot theme, quote or line, titles, etc. Occasionally he will expand on an idea by adding indented notes beneath it, using the indentation to imply owner-

ship to the parent idea.

Review of old notes is incredibly important to him, though he occasionally finds it difficult to keep track of ideas spread throughout the notebook. In fact, during the interview, he stumbled across an idea that he had forgotten about and hadn't seen since it was in a random section of his notebook; he then re-wrote the idea in a more conspicuous location and styling. This incident validated the benefit of efficient note review.

Once he has enough ideas and notices some trends in his ideas, he starts a new section of notes in the next open space. Here, he elaborates on the ideas in depth, though they are still rather disorganized temporally. Eventually, he compiles these ideas into a rough script, including a logical flow of the story.

He stated that he frequently uses two documents at the same time. For example, he will refer to his rough script ideas when writing a more structured script to make sure that he included everything he wanted to include. He would in turn refer to his hand-written script when typing up a digital copy.

Like the student before, he uses various forms of meta-notes to create meaning. When creating the script, he will use checkboxes to signal that he's already included an idea; this behavior could benefit from the "to-do" list behavior described in the context scenario.

Occasionally, he wants to modify the organization of some of his notes. For example, he may want to move a section of the script to somewhere further in the story. To do so, he draws a bracket around the notes, then draws an arrow – often spanning pages – to indicate where it should go.

Another commonly-used technique is drawing boxes around individual, separable sections of notes; he uses this especially to indicate a brief departure from the continuous notes before and after a given idea. When reviewing and supplementing existing notes, he often uses different colored pens so that he can tell the difference between old and new notes, especially on cluttered pages. To remove sections from a linearly-structured script, for example, he will cross out lines of notes.

Interestingly, he stated that he finds value in knowing when notes were made (e.g. when he crossed out a given note) because the context can provide clues as to why he did that. He noted that there's a difference between crossing out an idea immediately after writing it (he didn't like the idea right away) or crossing it out after the fact (e.g. during a group review of a script).

3.2.3 Case Study 3: Contractor

The final participant presented here is a general contractor who specializes in kitchen remodeling and cabinetry. He is self-employed and primarily completes jobs start-to-finish unassisted. His primary use for his notebook is to record agreements reached with clients and to sketch out kitchen designs. He stresses the importance of accurately recording and reviewing information for at least two reasons: (1) he is accountable to the client to satisfy the requirements they have agreed upon, and (2) misinformation could lead to costly mistakes, such as having to re-order cabinet doors.

He shows characteristics of both the student and screenwriter. He keeps his notebook organized to some extent, but in some cases he needs to deviate from strict organization. Like the others, he uses various mark-ups to classify and label his notes. For example, he uses checkboxes on his "hit list" – the high-level list of things he needs to accomplish for a given job.

Like the screenwriter, the contractor frequently viewed notes together, such as referring to a sketch of the kitchen when creating his list of materials he needs. Another example is when he draws a design on the left page of the open notebook while referring to notes on the right page. He describes yet another example in which he prints out the directions to a customer's house, then writes notes on the back of the direction page; he states that this helps keep the notes associated with the specific job.

Finally, the contractor expressed mild frustration about the strict format of his notes. While he tends to keep his notes grouped by job, there are times when he would like to group them by another criteria. For example, for each job, he makes a list of materials and supplies that we will need from hardware and lumber

stores. In the current state, he either needs to bring his entire notebook and skip through to locate each materials list or tear each list out and bring only those page (which separates the notes from their respective job).

3.2.4 Types of Notes

In addition to these interviews, some initial in-depth analyses of participants' notebooks were conducted to further discover the types of notes that were taken and the formatting that was used. Though more surveyance of notebooks is required, many types of notes have been revealed, supplementing those found by previous studies. Unfortunately, the static nature of these notes removes any data about changes in the note over time. Nonetheless, some valuable information is still obtainable.

Checkboxes were surprisingly common, yet the evidence suggests that note-takers don't always return to these checkboxes to mark them as complete. More investigation may be required to discover the value of these kinds of lists and why they are sometimes ignored. It may be that the lists aren't salient enough – perhaps that people don't return to them because they don't stand out and become lost.

There were many cases of boxes, brackets, and other markings being used to demarcate sections of text that are separate from the surrounding text. This was especially common when the boxed text was unrelated to the rest of the content on a page, as if it was a way of signaling that the boxed note doesn't belong here. Indeed, boxes and brackets were often accompanied by arrows "moving" them to other sections or pages (though arrows were also used to show relation between two separated notes). Of course, physical movement on paper is impossible, but may be supported digitally. Movement or reorganization was also suggested by using an asterisk to signal the desire to insert a note somewhere else.

Meta-notes were written in ways that made them visually distinct from actual content. For example, meta-notes were often written sideways in the margin, such as the screenwriter's labeling of scene numbers. Boxes were also seen around meta-notes, such as

labeling something as an "idea," likely to signal that the boxed note is not actual content.

Traditional methods of underlining and highlighting were also seen, primarily as a way of adding emphasis. In one case, highlighting was used to highlight things that had not yet been completed, which was interesting given a highlighter's relative permanence (i.e. they couldn't remove the highlighting when the complete the corresponding note).

3.2.5 Trends

In general, users displayed varying degrees of organization, but each expressed a desire, either explicitly or implicitly (through their notes), to have their notes organized in a way that would afford more efficient review. Participants made meta-notes that indicated a desire to move or re-arrange sections of their notes, while labels like "idea" and "equation" showed a desire to supersede the forced, linear structure of paper notebooks.

The participants often struggled to determine the importance or meaning of a given note, despite abundant markings and apparently clarity at the time the notes were taken. Context seemed to greatly help the participants to recognize what their notes were about; when users were unsure of a note, reviewing the surrounding content often revealed more information and allowed them to identify the note. This suggests that visualization of context may be beneficial and desirable in the design. In addition, participants expressed that they often liked to look at multiple documents simultaneously.

Participants also tended to express frustration with the visual search required to locate a particular note, especially for notes that were not made visually salient. Often, participants made meta-notes to label notes, which at least allowed a quick way to recognize the nature of a labeled note.

3.3 Proposed Research

While the ultimate goal of this proposal is to outline the design and creation of a note visualization tool, it would be worthwhile to conduct additional user

research before committing to a design.

3.3.1 *Goals*

Despite the numerous studies assessing the value of note-taking and note review, data regarding the effects of note organization is either missing entirely or obscure. The preliminary studies conducted above reveal a fair amount of information, but more research could reveal more note-taking techniques, as well as the actual value of these techniques.

Such research would help further motivate the design of a system to allow better visualization and review of notes.

3.3.2 *Methods*

In addition to continued interviews and notebook analyses, it would be valuable to try to empirically determine the true benefit of various note-taking techniques. The exact nature of such studies is difficult to predict, but would likely search for correlation between the times a technique was used and some measurement of the user's performance, such as time to complete a search, time to recognize the content of a note, or performance on mock or real exams given after a period of review.

It would also be incredibly valuable to analyze note-taking as it occurs. The studies so far have dealt with notes that had already been taken and thus lack true data about how the techniques were deployed. Shadowing people as they take notes in natural contexts would surely reveal valuable data about real practices.

3.3.3 *Expected Findings*

Inevitably, such research would reveal a number of new techniques that people use to create, label, and review their notes. As the goal of this project is to enhance note review, these techniques will be leveraged into a visualization system that allows them to be utilized in their natural manner as well as further enhanced.

4 PROPOSED DESIGN

Though only a limited amount of user data has been obtained thus far, there are several trends beginning to emerge, as discussed above, that should be addressed in the design of the system. With further research, more behaviors will be discovered. But there is already sufficient data to begin formulating initial design plans.

So far, three primary problem spaces have been identified. These spaces refer to common tasks related to the visualization of information after the notes have been taken and captured to a digital device. For each area, a variety of solutions are proposed. Ultimately, these design changes would be implemented in the final system, pending additional user research.

It's important to note that the proposed research and development concerns the visualization side of the process. Efficient capture, including support for notebook segregation and tagging, must be designed and developed as well.

4.1 Visual Exploration of Notes

The first problem area addresses the issue of exploring one's notes without searching for a particular item. Examples of this could include: the screenwriter reading over ideas that he has written down in the past in order to find inspiration, the student reviewing all relevant class notes for an upcoming exam, and the contractor scanning through his notes to make sure he didn't miss any "to-do" items. In each case, there is no single note in mind, but rather a goal of locating relevant items and efficiently understanding them. A large part of effective visualization may be the ability to understand note context and recognize salient features.

4.1.1 *Existing Problems and Implications*

Unless thought is given to organization ahead of time, the rigid and linear structure of a paper notebook affords a time-centric progression; many notebooks naturally progress from old notes to new notes, sometimes without separation by topic. Without topic-centric structure, it's difficult to see relevant context and follow the natural progression of a topic because of the switching back and forth between topics. That is, people can see the time-based context of their notes, but

it's probably not important for a student to see the history notes that precede their chemistry notes or the philosophy notes that follow. Instead, it's valuable to see the previous chemistry notes, which provides context and information about the general flow of that topic by itself. Thus, context is an important avenue to investigate, especially since it helped participants recognize their notes when it existed.

One smaller issue that was raised during interviews was the fact that paper-based notes are static and reveal no information about changes over time unless specifically encoded by the note-taker (e.g. the screenwriter would occasionally use different colors of ink with each new session on a single page). An efficient design would take this into account and allow for some exploration of this data.
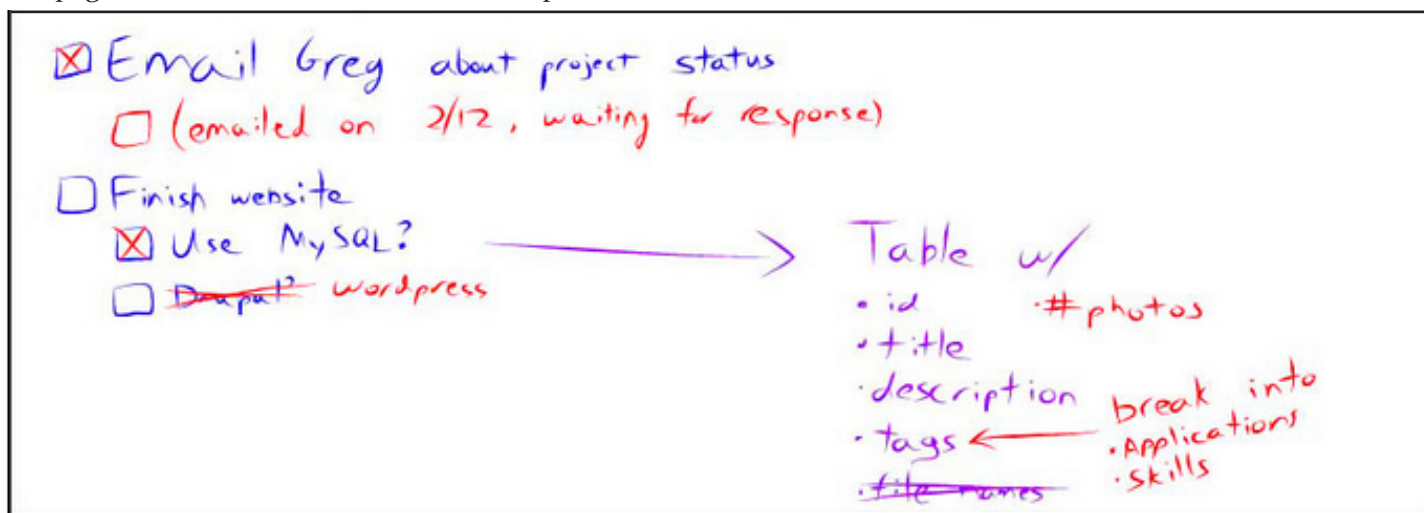
Finally, the use of meta-notes like labels, checkbox "to-do" lists, and reminders presents a problem in that these are only salient when the person is viewing that page; when the notebook is closed or open to a different page, those features lose their saliency and are often ignored.

4.1.2 Proposed Solutions

With regards to context, an important function to support is varied sorting of notes within a single topic. For example, in some cases it might be beneficial to view notes by the date they were first created, which would provide context regarding the flow of the original information. Or it may be valuable to view data by the last modified date, which would give context to recent changes.

The screenwriter further described a desire to see context beyond the surrounding notes. Sometimes he makes revisions to his scripts while on conference calls with his colleagues, and being able to see that changes he made coincided with an appointment on his calendar would be valuable to understanding the motivations. It would be worthwhile to incorporate some sort of time- and location-aware data, such as syncing

Figure 3: A sample note containing three different revisions: (1) on February 2, marked in blue; (2) near February 7, marked in magenta; and (3) on February 12, marked in red. The user may enable time-based coloring or disable it to see the notes as they would appear on paper (i.e.g all in black).

The user may find it useful to see when modifications were made. For example, the note for "Drupal" was crossed out 10 days after it was written, while the note for "file names" was crossed out the same day it was written. Time-based information like this can reveal subtleties that static notes cannot.

to a user's calendar and a GPS device, to provide further context that might help a user understand exactly why a note was made or modified. The screenwriter's use of different colors of ink to signal later additions to his original notes could be an automated option so that users can see the different time-based layers of their notes (figure 3).

Some context may transcend the basic time-based structures even within a single topic. It may be beneficial to see a visual representation of the connections between documents – i.e. how often the user switches between two documents. For example, each time the user switches from writing on page A to page B, the connection from A to B is strengthened. A linkage system like this may also support both implicit (described above) and explicit linking (e.g. a user manually and purposely specifying that the link between two notes should be strong). A force-directed layout (Stanford Visualization Group, 2010) could be used to show these relative strengths of connections (figure 4). Such a visualization could allow the user to quickly access notes that are relevant to each other or commonly used together.

To address the issue of the often hidden nature of features meant to highlight notes, a system of expos-

Figure 4: A force-directed layout could display the strength of connections between notes. In such a visualization, a higher number of switches between two notes might be represented by thicker lines and closer proximity. Further, changes in the thickness of lines between two document may signal the primary direction of switching. Overall, force-directed layouts tend to naturally group related items.

ing these features would undoubtedly be beneficial to users. Upon accessing their digital notebook, the user could see a listing of the number of each emphasizing note. For example, without opening a specific note, a user could quickly see that he has 12 unchecked "to-do" items, despite the fact that they are spread out across multiple notes and would otherwise require a survey of each note individually.

Overall, the revelation of context, visualization of inter-note connections, and increased saliency of features meant to highlight notes serve to enhance and augment the natural exploration of notes.

4.2 Explicit Search of Notes

As expected, when looking for particular items, participants found visual search of notes to be difficult, especially with longer periods of time passing between when the note was created and when it was accessed.

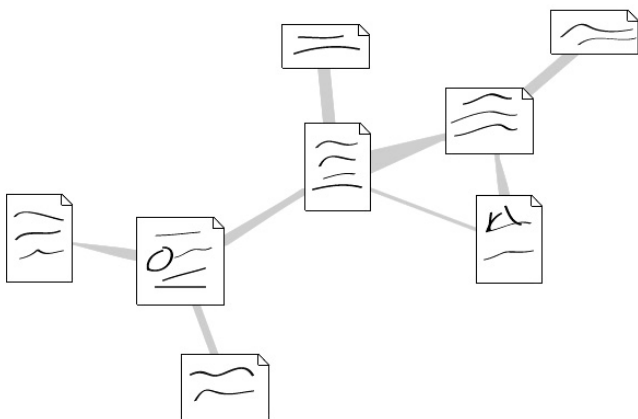### 4.2.1 Existing Problems and Implications

As noted before, paper-based search is confined to visual scanning, though salient features can be used to make items stand out. Still search remains a difficult process because it relies entirely on human cognition.

4.2.2 Proposed Solutions

Search can be augmented through digitization of notes and meta-notes. As discussed previously, tags could be beneficial by providing categorical classification that can be used to find specific notes.

Using the paper interface, a user could mark a section of their notes with by touching a button for the associate tag. During initial setup on the computer, users would likely synchronize the paper-based tag with a digital text-based version (e.g. the user might be asked to transcribe the hand-written tag so that the computer can associate the text with the note) – this behavior is dependent upon the interaction design of the pen, and is beyond the scope of this proposal, which assumes that all appropriate capturing has been done effectively.

The use of tags would give users a way to categorize information at a higher level that might lend itself to better search, especially if the user is presented with a
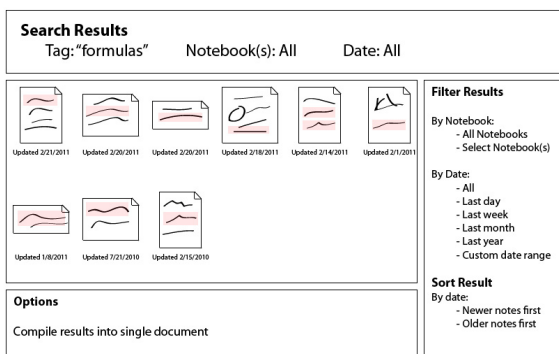
list of tags; they would only need to rely on recognition rather than recall as the users could click on individual tags instead of typing in a search term.

Tags could be used to span multiple topics or notebooks. For example, the contractor could have separate notebooks for each customer, but use the tag "materials" in each notebook. Later, at the digital interface, he could choose multiple options for finding the correct note or notes: he could select (1) to view all notes tagged with "materials," which would reveal notes from multiple notebooks (figure 5); (2) to view all notes from the notebook "Wilson Kitchen" to see all the notes from that notebook; or (3) to view all notes at the intersection of the tag "materials" and the notebook "Wilson Kitchen" to quickly find the single page of notes that includes the materials for the Wilson job.

It seems apparent that tags would be an effective way to search for categorizable notes, as long as the user included a tag. Research into the likelihood of users creating and using tags should be further investigated before full implementation.

4.3 Reorganization of Notes

Paper inherently presents a problem in that it forces a strict organization without much ability to change organization later on. Conceptual organization is not linear, but can exist in an overlapping hierarchy. Therefore, the ability to access notes from multiple paths, such as through searching by tag, is valuable.

The issues of reorganization were visited above in the discussion on visual exploration, since exploration can rely heavily on organization. The ability to categorize notes into particular notebooks and with different tags has been proposed above. However, some issues still remain.
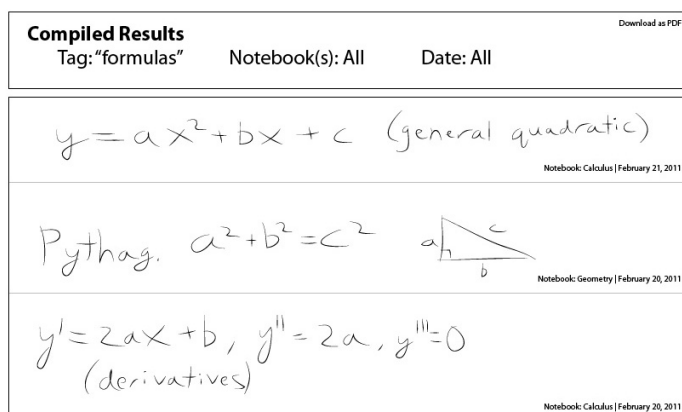
4.3.1 Existing Problems and Implications

One issue that arose with paper notes was the inability to see all instances of a particular type of note at one time. For example, if the screenwriter wanted to see all of his ideas for characters, he would have to flip through many pages to see each idea.

At a lower level then tags and notebooks, another observed behavior was that users would draw boxes, arrows, and asterisks to signal that they wanted to move a note to somewhere else in their notebook.

4.3.2 Proposed Solutions

Proposed above is the ability to see all notes with a specific tag by using a search tool. While this would quickly allow access to each note individually, it would be nice if the user could compile individual listings into a single page or a new section of notes.

Therefore a proposed solution would be to allow the user to take any number of notes from a search result and compile into a new document (figure 6). The screenwriter would be able to see all his character ideas at once, which may allow him to make comparisons or

Figure 5: a wireframe mock-up of the results of a tag search. Users would be presented with all notes matching the searched tag, with the location of the tagged item on each page. Additional filter options, such as notebook and date, would be available to allow the user to search even more specifically.

Figure 6: A selection of notes from a search result could be recompiled into a single continous section. Here, a user has compiled all notes with the tag "formulas" into a single sheet with the intention of downloading the restructured page as a PDF and printing it out.

find links between characters, further assisting in developing a film idea. The feature would also benefit students who might want to see all their formulas on one page, like the user described in the scenario presented above.

The ability to see the desired changes in location of notes by the drawing of arrows should also be supported. PapierCraft, as described above, already supports such recomposition, and this technique could be incorporated into this project as well.

5 Conclusion

Following user research and design formation, a detailed specification will be produced.

Initially, a prototype will be built using web technologies like XHTML and JavaScript, since they allow for rapid prototyping. At first, the prototypes will use mock-data rather than actual data from a pen, but will eventually implement real pen-based data.

The technique of iterative design will be used, so users will be involved in usability testing throughout the process. Evaluative techniques are still to be determined, but will likely involve both qualitative and quantitative analysis of the ease of use, likelihood of use, and improvement in efficiency over paper notes. Actual implementation will follow, using the designs generated through this iterative process.

Overall, this proposed project would enhance users' ability to view and understand their notes, which may have important implications on their performance following note review.

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