HyNote: Integrated Concept Mapping and Notetaking

Xiaojun Meng[1,2], Shengdong Zhao[2], Darren Edge[1]

[1]Microsoft Research
Beijing, China
darren.edge@microsoft.com

[2]NUS-HCI Lab, National University of Singapore
Singapore,117417
{xiaojun, zhaosd}@comp.nus.edu.sg

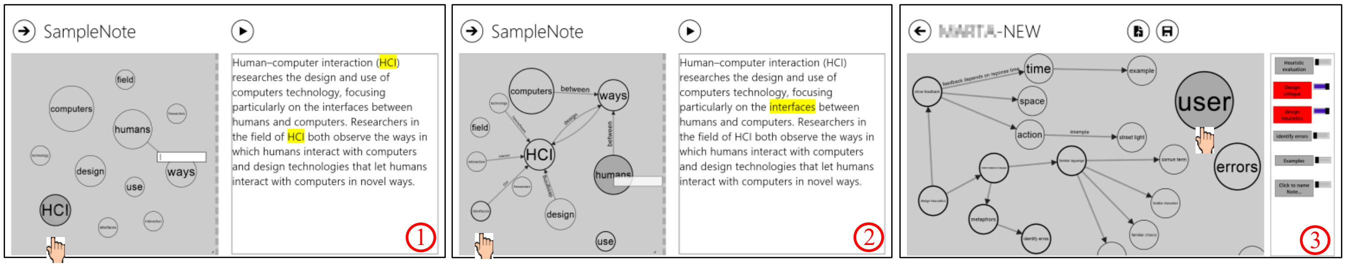

Figure 1. How to perform hybrid note-taking: (1) Note-takers write raw notes; HyNote extracts key concepts and creates corresponding concept bubbles; Note-takers can connect concept bubbles into a concept map; (2) Note-takers select concept bubbles to highlight references in the note text, aiding search and cross-referencing; (3) Note-takers can create a connected concept map from all concepts and relationships in selected notes; the large concept bubble for "user" was generated from multiple notes. Notes (1) and (2) were copied from Wikipedia to explain the notion of "HCI". Note (3) was made by participant P1 in our study.

ABSTRACT

Notes can be taken in a linear or nonlinear way. Previous work suggests that nonlinear note taking is advantageous in terms of sense-making and long-term recall. However, previous studies also reveal that the combination of divided attention and time pressure make realtime notetaking a challenge. In this paper, we propose a new hybrid workflow inheriting advantages from both linear and nonlinear notetaking approaches. Our resulting HyNote (Hybrid Notetaking) system uses statistical parsing of linear raw notes to facilitate concepts mapping, allowing users to smoothly switch between linear and nonlinear approaches with low effort and time costs. Results from our preliminary study of HyNote show that users can easily map concepts in realtime and achieve superior understanding of lecture contents in a video learning task compared with using the traditional linear Notepad application.

Author Keywords

Notetaking; Concept Mapping; Mobile interaction

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces

1. INTRODUCTION

Notetaking is a widely-used cognitive technology to offload cognitive processes and extend people's cognitive abilities [6]. Many systems (e.g., [1][3], [7][9]) have attempted to improve notetaking, from enhancing efficiency to enriching the user experience. However, very few systems have tackled the problem of how to integrate sensemaking with realtime notetaking.

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Generally, notetaking techniques can be divided into linear and nonlinear approaches. Linear notetaking captures raw notes in the order that the information is received, in the form of narrative sentences or bullet points. In contrast, nonlinear notetaking uses more spatial visual representations to record non-sentential notes [1]. A particularly well-established form of relational diagram commonly used for nonlinear notetaking is the concept map [5].

Existing research work (e.g., [2][3][6]) has shown that nonlinear notetaking, e.g., with concept maps, has significant advantages over traditional linear notetaking in terms of enhancing the sensemaking process. One particular study showed that students using the cognitively-compatible technique of concept mapping increased their academic performance through deeper understanding and more integrated knowledge management [6].

However, concept mapping is not a straightforward technique to use in realtime learning scenarios. Kaivola et al. [4] conducted a study to establish how students in Computer Science use concept mapping as a note-taking technique during lectures or studying in general. They reported that learners experienced difficulties taking nonlinear notes because the rhythm of the lecture was too fast to organize them, leading students to lose focus on the lecture itself.

Linear and nonlinear notetaking approaches offer complementary benefits in scenarios where both notetaking and sensemaking need to occur in realtime, such as in lecture-based learning. Linear notetaking, especially in the form of abbreviated bullet points, is a simple and efficient way to capture incoming information whose organization is not known in advance [4]. Conversely, nonlinear notetaking facilitates sensemaking by requiring deeper and more active cognitive processing of the underlying concepts and their interrelationships [6]. To inherit advantages from both approaches, we propose a hybrid note-taking technique, implemented in our HyNote system, in which the user can freely switch between linear notetaking and nonlinear concept mapping. The system facilitates this process by automatically extracting "concept bubbles" from the user's text notes, ready for connection by the user, and dynamically visualizing the resulting concept maps for both individual notes and note collections (Figure 1).

In a formative user study, use of HyNote led to superior understanding of video lectures compared with use of the NotePad application, showing promise for hybrid notetaking in general.

2. RELATED WORK

Existing notetaking systems from the HCI literature have tackled various aspects and forms of the activity. TextTearing [9] facilitates digital ink annotation on existing documents via in-situ expansion of inter-line whitespace. InkSeine [3] is a pen-based tablet application that supports active notetaking with in-situ search of ink notes. Finally, InkAnchor [7] provides a digital ink editor for finger drawing and writing on the smaller spaces of mobile touchscreens. While commerical products like Evernote and OneNote can be used for realtime notetaking and provide some nonlinear features, such as drawing diagrams and linking resources, the compexity and time cost of manually mapping and linking notes could provide a significant barrier to realtime use.

From prior studies, we know that even for linear notes, both typing and arranging text provide a meaningful contribution to the sensemaking process [1]. Prior work has also demonstrated significant advantages of nonlinear notetaking over traditional linear techniques [2] [6]. However, Kaivola at al.'s study [4] found that direct nonlinear notetaking is not easy to perform in realtime.

Automated concept mapping could help to reduce the time and effort required to build concept maps. For example, the system of Zubrinic et al. [10] mines concepts from textual sources and constructs concept map relations based on language syntax. This work builds on the tradition of automated keyphrase extraction [8], which can help humans gain a quick sense of long documents. Extended text notes are a promising target for such an approach.

Overall, existing systems have not yet shown that sensemaking can be performed successfully during realtime notetaking. Nonlinear note forms are a promising solution, but they are difficult to construct in realtime and their potential integration with linear notes remains a design challenge.

3. DESIGN RATIONALE

From participant feedback in the study of Kaivola et al. [4], we identified two key problems for realtime concept mapping:

a) **Divided attention**. Students usually have no idea about the substance of lecture beforehand, and identifying and connecting key concepts requires strict attention. It can also be extremely difficult to follow what the lecturer is saying while simultaneously deciding and recording how it relates to new or existing concepts. Realtime concept mapping can thus create a significant distraction that causes delivered information to be missed or misunderstood.

b) **Time pressure**. Students found it challenging to map concepts in the live lecture because of its quick rhythm and their tendency to focus excessively on the visual aesthetics of their concept map (balance, hierarchy, clarity, etc.). Directly drawing the concept map is itself a time-consuming task, made all the more stressful by the need to make permanent decisions about its content and structure under time pressure and uncertainty of what is to come.

One participant also noted that "*It is probably easier to make the concept map based on the text because it can be directly processed after having read the text*". This concept solves the problems of divided attention and time pressure because when the pressure is on, the user can simply take linear notes. When the pressure is off, the user can pause, reflect, and record new-found understanding by constructing concept map relations between existing text elements. This concept forms the foundation of our new approach.

4. DESIGN

4.1 Hybrid Notetaking Process

As shown in the Figure 2-a, there are two panels for users to take notes in this new technique. The right panel is used for linear notetaking in which raw text and bullets can be typed in any form. The left panel is used for nonlinear mapping of concepts automatically extracted from the raw notes and displayed as "concept bubbles". Note-takers can perform simple gestures to connect these concepts into a concept map for the note.

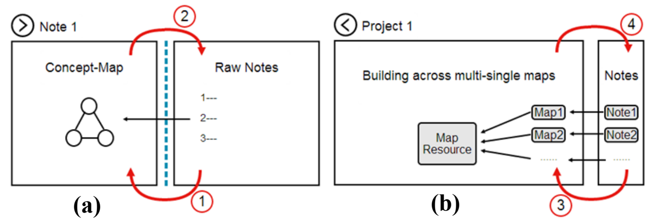

Figure 2. (a) Hybrid note-taking process: (1) concept bubbles generated from raw notes; (2) connected concept bubbles form a concept map that aids sensemaking. (b) Multi-note review process: (3) individual notes contribute their concepts and relations to a globally-connected concept map; (4) global understanding and navigation support future notetaking.

4.2 Multi-Note Review Process

After taking individual notes, users are able to work on all single maps together to build a globally-connected concept map. As shown in Figure 2-b, note-takers can toggle the state of each note in the right panel to be either "visible" or "invisible" in the left larger panel. Users can add to this connected concept map with further notes, expanding the role of the system from realtime notetaking to long-term knowledge management.

4.3 Overall Workflow

To facilitate hybrid notetaking and review, we describe a new workflow for taking notes and how it is able to serve note-takers. This 4-step process follows the numbered red bubbles of Figure 2:

1) When starting to take notes, users typically have no idea about the content to come or its overall structure. In this phase, users can simply keep writing raw text notes into the right panel. All key concepts in the raw notes will be identified automatically and used to generate concept bubbles that appear in the left panel.

2) With a certain amount of notes taken, users will gradually make sense of the big picture. They can continue capturing raw notes as required, but also begin building a concept map using simple gestures on concept bubbles. Users can focus on either panel at any time, moving between them based on the pace of the speaker and their current level of understanding and cognitive load.

3) Note-takers often need to take multiple notes about the same topic. It is tedious to scan, review and search across multiple notes, especially when they are not all located in the same place. HyNote allow note-takers to easily create, modify, and review individual notes, as well as to integrate new concepts into their globally-connected, automatically-generated concept map.

4) Building an entire concept map assists note-takers with the review of how concepts relate across multiple notetaking sessions, clearly viewing the relative importance and interconnectedness of concepts. This high-level visual representation can potentially help users develop a better understanding of the material, promote superior long-term recall, and prompt the addition of new notes that relate to properties of the emergent concept map.

5. IMPLEMENTATION

We implemented our proposed workflow in HyNote – a Windows Store application written in WinJS. HyNote runs on Windows 8.1 tablet devices on which note-takers can take notes using a touch or physical keyboard, and map concepts using touch or mouse gestures. HyNote use is illustrated in Figure 1.

HyNote regards noun phrases in raw notes as potentially meaningful concepts. It extracts concepts from raw notes and automatically generates concept bubbles, even when the raw notes are not complete sentences. HyNote parses noun phrases using two sources: (1) a powerful statistical parsing and linguistic analysis toolkit, SPLAT[1], which can accurately detect proper noun phrases from raw notes; and (2) a list of proper nouns, the Great noun list[2], which contains a large vocabulary of proper nouns against which raw text can be matched. Users of HyNote can modify and personalize their own noun lists as desired.

HyNote concept mapping is performed using the flexible force-directed graph layout[3] from the D3 library, and thus can help note-takers modify concept map layouts in a physically-constrained and intuitively understandable way. The result is an aesthetically pleasing and legible concept map regardless of the user's artistic talent. Such automated layout avoids overlapping concepts or committing concepts to fixed locations in space, thus allowing for organic, note-directed growth of the concept map over time.

Each concept bubble has three states: *Free*, *Fixed* and *Selected*. A bubble is first created in a *Free* state in the force-directed graph layout. When the user drags a *Free* bubble, it takes on a bold border, becomes *Fixed* in the layout of the panel to support connection to other concept bubbles, and highlights the corresponding text in the raw notes. When the user taps a *Free* or *Fixed* bubble, it becomes darker in background color and *Selected*. Any *Selected* bubble also occupies a fixed position in the layout. Tapping a *Selected* bubble toggles the selection away and the bubble becomes *Fixed* only. Double tapping makes a bubble *Free*.

Interaction with concept bubbles is based on the "Seven golden rules" [5] for concepts mapping, which state that *"each concept can only be written in one place on the map, and link words or phrases are written on every linking line to describe the relation between two concepts."* Therefore, identical concepts with their linked relations are self-merged in an animated fashion that can be easily recognized by note-takers. As Figure 1 shows, the frequency of concepts appearing in notes determines bubble diameters according to a logarithmic function, and the font size of concept labels is set such that they fill their containing bubbles. The underlying data-binding enables note-takers to easily identify the most frequently appearing concepts. In addition, selecting a concept when another concept is already *Selected* links them in the direction from the first *Selected* concept to the second. Note-takers can type the link name upon its creation or edit it later by tapping the link. A *Selected* bubble is also editable (for text update and bubble deletion). Double tapping white space pops up an empty bubble that allows note-takers to create concepts directly.

In the force-directed layout, *Free* bubbles are loosely anchored to the central position of the layout, and flow around other bubbles as a result of a repulsive force, except that two interconnected bubbles are subjected to an attractive force. *Fixed* and *Selected* bubbles are repositioned by the note-taker.

In the multi-note review process, selecting concepts highlights all contributing notes, as shown in Figure 1-3. Users can zoom out to an overview, and zoom in to update details of individual maps.

6. EVALUATION

To investigate the extent to which HyNote supports realtime notetaking and sensemaking, we conducted a preliminary user study comparing it with a linear note-taking approach using Notepad. The task tested realtime learning from lecture videos.

Participants. 8 participants (2 males) ranging from 23-28 years old (M=26, SD=2.13) voluntarily participated in this study. The participants were local university students with diverse academic backgrounds. They were highly experienced with notetaking but none of them had any prior knowledge of HyNote.

Apparatus. Lecture videos with default subtitles were played on a Windows 7 PC with a 2.4-GHz i7 4GB Intel processor and 23" Samsung display at 1920x1080 resolution. Both HyNote and Notepad were running on a Windows 8.1 Samsung tablet PC with a 1.8-GHz i5 4GB Intel processor.

Tasks. We used the Stanford Human-Computer Interaction video lecture[4] from Coursera, given by Scott Klemmer. The lecture introduces heuristic evaluation (ten key heuristics of good design) from the HCI field. Participants did not have existing knowledge of the video or its contents. They were asked to watch this video course and take notes using the assigned note-taking application to gain a better understanding of the course.

The total lecture video was divided into two parts (v1, v2): The v1 video (10 minutes) introduces basic background knowledge and the first half of heuristic evaluation. The v2 video (8 minutes) introduces the remaining part of heuristic evaluation. After watching both videos, participants were required to complete a quiz with 14 questions. 7 questions were examining knowledge from each of v1 and v2. They tested understanding of heuristic evaluation and the connections among different design heuristics.

Each set of 7 questions included 6 multiple choice questions (single answer) and 1 fill-in-the-blank question. All questions were presented in a random order during the quiz. The marking scale was decided prior to the study and the conductor marked all quizzes together (blind to both participant and condition).

Design and Procedure. A within-subject design was used. Each participant watched both videos (v1, v2) using both systems (HyNote, Notepad). The order of system use was counter-balanced while the order of the videos remained the same.

At the beginning of the experiment, participants were asked to complete a pre-questionnaire regarding their demographic information. Then the conductor briefly introduced the purpose and procedure of the user study as well as HyNote and Notepad. Participants had a 10-minutes practice session on the two systems. Participants then started to watch videos (v1, v2) and take notes using a specific system in the pre-defined counter-balanced order. When participants were using HyNote, we recorded the time spent on nonlinear concept mapping, although use of this technique was not a requirement for task completion. Participants were not allowed to pause, fast-forward or rewind videos, to mimic an actual lecture. After watching videos, participants were allowed to review the notes taken with both systems and complete the quiz. Finally, participants completed a post-quiz questionnaire and provided feedback. The experiment took approximately one hour.

[1] http://research.microsoft.com/en-us/projects/msrsplat/

[2] http://www.desiquintans.com/nounlist

[3] http://bl.ocks.org/mbostock/4062045

[4] https://www.coursera.org/specializations/interaction-design

Results. A paired t-Test with 5% alpha-level revealed that there was a significant effect of system type on the post-quiz scores. As shown in the Figure 3, when participants used HyNote (M=5.6/7) they achieved significantly higher quiz scores than when they used Notepad (M=4.8/7) to take notes ($t = 2.51$, p-value=0.04). This corresponds to an additional 11.4% score in the post-quiz when using HyNote compared with using Notepad to take notes. As Figure 4 shows, on average, participants voluntarily spent 19.4% of their time constructing concept maps while using HyNote.

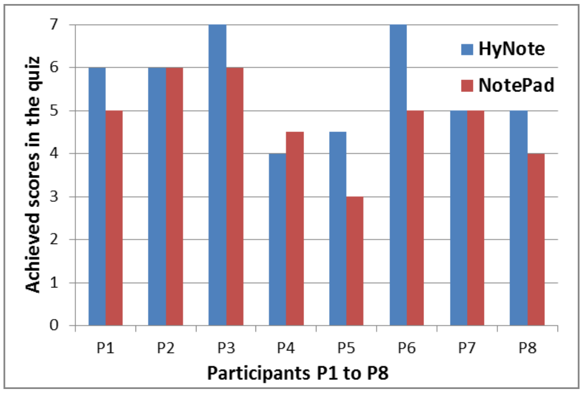

Figure 3 : Comparison of individual quiz scores using the two notetaking systems.

In addition to the results above, the feedback on HyNote was overall positive. In particular, participants preferred HyNote over Notepad because HyNote could help them easily detect underlying relations among notes (M = 5.25, 1=strongly disagree; 7=strongly agree). Participants volunteered that the way in which HyNote automatically retrieved key concepts and helped them construct concept maps saved them time (P1, P2, P7, P8) and helped them to feel more productive when notetaking. Participants also found HyNote more helpful to understand and review notes taken from multiple lectures because it "*is easy to see relationships of concepts after the lecture*" (P2) and it "*combines several notes together when one wants to revise notes*" (P3). In line with our initial design rationale, participants also described how they could effortlessly map retrieved concepts in fragments of spare time without losing focus on the lecture. Overall, we were also generally impressed by several well taken "HyNotes" constructed by our study participants in such a limited time (Figure 1-3).

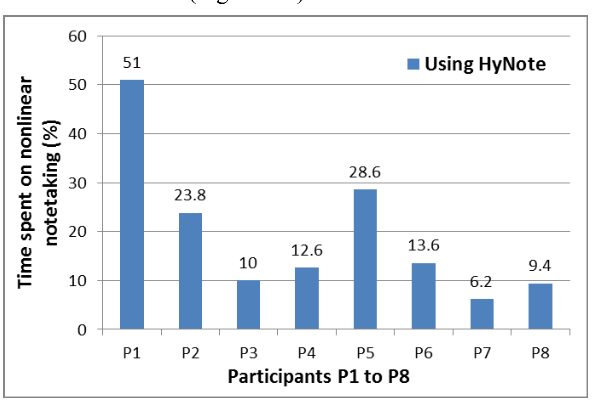

Figure 4 : Percent of time each participant spent on nonlinear notetaking (constructing concept maps) while using HyNote.

7. LIMITATIONS & FUTURE WORK

HyNote is only an initial step towards bridging the gap between linear and nonlinear forms of realtime notetaking. Our system certainly requires more learning than a simple notepad application, and it may not meet the needs of individuals with diverse and ingrained notetaking habits. For example, three participants in our study (P3, P5, P6) were concerned that HyNote may still distract new users, especially when material is difficult to understand.

Additionally, if the note domain does not involve many relations, or if the actual key concepts are not recognized, then HyNote may only provide limited support to the sensemaking process. Future work is to compare HyNote to non-linear concept mapping tools, and also to understand how well hybrid notetaking applications like HyNote can support long-term notetaking and knowledge management across many dispersed sessions, as well as content search, review, and application in real use contexts.

8. CONCLUSION

We propose a novel hybrid workflow for realtime notetaking that inherits advantages from both linear and nonlinear techniques. This workflow was designed to guide and assist note-takers in switching smoothly between these two techniques, and potentially address limitations revealed by research studies in the literature. We implemented this design in HyNote, a Hybrid Notetaking system supporting realtime linear notetaking integrated with concept mapping. Preliminary study results show that users regarded HyNote as easy to use and a more productive way to identify and record key concepts and their relationships. Overall, use of HyNote led to superior understanding of video lectures compared with use of the NotePad application, showing promise for hybrid notetaking in general.

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