Note-Taking in Virtual Reality Using Visual Hyperlinks and Annotations

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Abstract. Immersive virtual reality shows great promise for teaching and learning, but the question of how best to apply the powerful practice of note-taking has been explored very little. In non-VR settings, research has shown significant differences in learning outcomes depending on the usage of different styles of note-taking. Active "long-hand" notes sometimes work better than "verbatim" or typed notes, suggesting that in VR, recording and playback alone as a form of note-taking is unlikely to be optimal. We imagine a new form of active note-taking in VR that uses long-hand but also leverages recordings and original source learning materials. The approach is to use a virtual scrapbook that contains visual snapshots that function as hyperlinks along with hand-written notes. We hypothesize that this will be superior to either form of traditional note-taking for learning complex and abstract concepts. We discuss our work-in-progress towards building a note-taking system that will help test this hypothesis.

Keywords: virtual reality, note-taking, learning

1 Introduction

Note-taking is a powerful tool to enhance comprehension and recall in learning activities. Immersive virtual reality shows great promise as a platform for engaging learning experiences that convey complex concepts and involve large corpuses of knowledge. The important question of how to take notes in virtual reality has not yet been explored in great detail. In this paper we lay out a set of design considerations for VR note-taking tools, and propose a promising approach that we are actively exploring. Section 2 provides background on the role of note-taking in learning. Section 3 poses the theoretical problem of note-taking in virtual reality, and Section 4 presents our approach of using a scrapbook of snapshot-based hyperlinks and annotations. In Section 5 we conclude with a discussion of future research directions, highlighting both challenges and opportunities.

2 Background: The Role of Note-Taking in Learning

Note-taking is a powerful tool for enhancing the effectiveness of learning activities, which goes back at least to ancient Greece, where the early form of the notebook was known as a *hypomnema*. Two functions performed by note-taking are (1) capturing the information that a learner is exposed to (*external storage*), which allows the information to be reviewed later, and (2) facilitating deep understanding through paraphrase, summarization, and so on (*encoding*) [6]. Due to the limitations in *working memory* [1], it has been observed that note-taking imposes a tradeoff between production and comprehension – the more time and attention that is devoted to the writing of notes, the less there is to devote to understanding the content [6]. When more time is devoted to production, notes tend to be "verbatim," and this style of notes is known as *non-generative* since it does not require or reflect that the learner has understood the material, whereas when more time is devoted to comprehension, notes can be *generative*, capturing the output of a process of idea synthesis [5].

Formal studies of the impact of note-taking disagree on its learning value. As highlighted by Lin and Bigenho [3], variations may be explained by differences in cognitive load associated with the particular systems and content in question. This is supported by their study showing that introducing distractions changes which of several note-taking methods yields the best learning outcomes [2]. A recent study that pitted an HMD-based VR learning system against a slide-show based learning system on a 2D display found the latter to be more effective, noting that note-taking was only possible in the non-VR system [4]. Taken together, a valid hypothesis remains that, with careful attention to the cognitive load imposed both by the environment and system affordances, it is possible to design learning systems (e.g. in VR) with support for note-taking that yield better learning outcomes than their counterparts without note-taking.

3 Theoretical Considerations

In virtual reality, experiences can be recorded and played back in a straightforward way. That is, a certain form of "verbatim notes" can be made available without any attentional effort. This frees up more attentional resources to devote to comprehension, but as noted above, generative note-taking is helpful in maximizing comprehension. As such, it seems clear that a form of active note-taking that also leverages the availability of audio/video recordings of VR learning experiences would be a promising possibility to explore.

We propose an approach leveraging "hyperlinking" as a rapid form of active note-taking. This means using a system affordance to choose a location in the learning content to refer back to later. Since this process is active– deciding and declaring that a moment is significant– we argue that a benefit associated with generative note-taking will be attained. Subsequently, when hyperlinks are reviewed, the content is accessible in its full original detail, allowing the learner to reap the benefits associated with verbatim note-taking.

3.1 Capture System: Snapshots as Visual Hyperlinks

Different kinds of snapshots can captured, and all of them can be used as hyperlinks. 2D snapshots are a familiar, lowest-common-denominator way of capturing visual information. Because the environment is captured in 3D, though, 3D notes are also a possibility. These can be a static snapshot of a scene that can be revisited later, and this can be accompanied by one or many camera positions that the learner finds useful or enlightening. Traditional notes can be tied to entire scenes or to specific camera positions. When the 3D content is animated, the possibility of temporal hyperlinks arises. Snapshots may have multiple representations: 2D images small (thumbnails) and large can be embedded in 2D notes, or 3D snapshots (small and large) can be used but it is less obvious how. Animations can be represented as a series of keyframes that may be presented in parallel in space. One consideration is that it may be of significant value to design notes to be easily viewable on mobile devices and allow the review process to be more portable. 2D snapshots and hand-written notes do have this property, and this is a major reason to consider them as a central building block for a VR note-taking system.

3.2 Synthesis through Annotation

Within this framework, we ask the question: what do active, synthesized and generative notes look like in VR? We assume that the learning experience itself is made up of visual and auditory experience. To begin, traditional handwritten note-taking is a possibility, assuming it can be captured and displayed at sufficient resolution, as shown in e.g. [7]). Synthesized notes can contain multiple hyperlinks, and the corresponding snapshots can be annotated with sketches and handwriting. Hyperlinks that are not embedded in notebooks may also be useful – similar to post-it notes used to mark important pages or chapters in a textbook.

3.3 Review System

We have proposed that notes may consist of visual hyperlinks embedded within hand-written virtual notebooks. Using such notebooks, the review process would consist of decoding the meaning from the "traditional" notes directly, and following hyperlinks to view the original content again. It should include viewing new external sources of information from the Internet, as this is a natural way to get different perspectives on concepts. This has several implications: one of these is that the note-taking system itself needs to support usage during the process of review. Just as with paper notebooks – more notes can be added to the notebook as it is being reviewed. In this case, however, the methods of interaction and representation need to be carefully considered. With ability to link back to recordings taken during use, the layering of different "real-times" can quickly get out of hand (replay the lecture, then replay yourself taking notes on the lecture, then replay yourself taking notes on the replay of the yourself taking notes on the lecture). For this reason it is critical that the review system provide a simple set of abstractions that supports multiple sessions of exposure and editing while keeping the complexity of linking to verbatim notes under control.

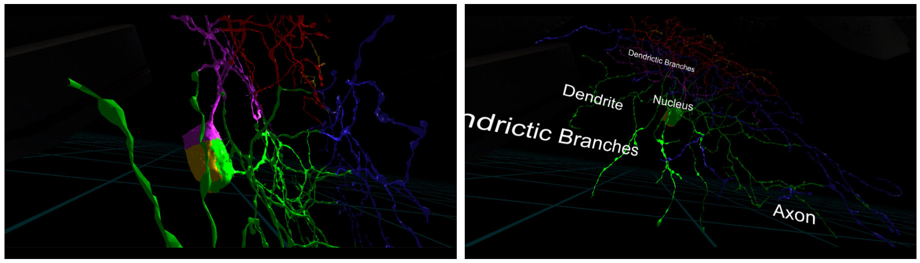

Fig. 1. The BrainVR environment allows learners to explore 3D neurons. Labels for neuron parts can be displayed.

4 Works-in-Progress: Note-Taking Using Visual Hyperlinks and Annotations

As alluded to above, we are exploring note-taking techniques based on virtual 2D "photos" that a user captures explicitly and intentionally. These photos assist learning in at least three ways: (1) their contents can help the user see and remember the insight gained, (2) they act as hyperlinks to return to the original position and environment configuration, (3) they can be incorporated into synthesized notes with sketches, collages, etc. We have implemented this idea in two variants – one that saves object perspectives, and another that saves spatial locations.

Our first implementation, shown in Figures 1 and 2 is a *perspective hyperlink panel*. The learner holds a complex object (example: neuron) in her hand which she is attempting to learn about. She can view it from any perspective by moving her hand and head, and can also rescale it using the controllers. She wishes to save and share insightful perspectives – these are defined by an orientation, camera position, and level of zoom for the object. A button on the controller allows her to take a snapshot of the perspective. The perspective is then added as a graphical thumbnail to a panel. Touching the corresponding thumbnail rotates the object to match the original perspective (regardless of the current orientation of the handheld controller). This application was built with the Oculus DK2 and Sixense STEM system. Our initial trials showed this to be a very effective and intuitive way of sharing perspectives of objects. As such, it is a solid building block for the note-taking system we envision.

In our second implementation is a *spatial scrapbook*, shown in Figure 3, the user explores a giant model of a human heart by moving around in 3D space. The size of the heart is such that arteries appear roughly large enough for an automobile to pass through. In this use case, the learner wishes to save locations and perspectives within a complex landscape. The user navigates the landscape by using the handheld controller to fly in any direction, with a velocity vector defined by a hand motion. He can take photos, sketch on the photos and arrange them on a canvas or book that travels in front of him like a portable drafting table. The photos can then be used as spatial hyperlinks to return back to the

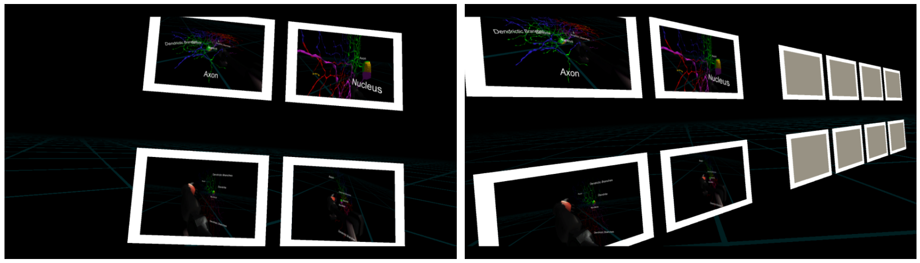

Fig. 2. The hyperlink panel captures object perspectives. New hyperlinks populate the gray squares.

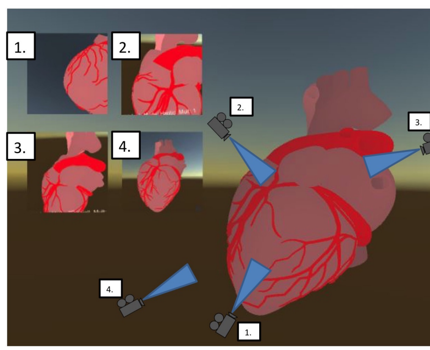

Fig. 3. The spatial scrapbook captures camera perspectives from different locations in a space or model.

location where they were taken in the original 3D environment. This application runs on the HTC Vive. Our initial trials show this to be an effective way of organizing information gathered through exploring a large, complex landscape with details in different locations and at different scales. One shortcoming is that abrupt transitions between locations are jolting and make it difficult for users to infer spatial relationships between locations. We are exploring solutions involving eased linear motions, and visual guides to indicate the path between locations.

Moving forward towards testing our hypothesis that this new form of note-taking is superior to note-taking in traditional settings, we are exploring methods for integrating 2D textbook materials into the 3D environment. This way, challenging 3D concepts can be presented with the advantages of motion-tracked virtual reality, while concepts that are well expressed in writing and 2D diagrams can be presented as such.

5 Conclusion

Given that note-taking practices vary widely between individuals and even within the practices of single individuals, there is no reason to believe there will be a one-size-fits-all solution for virtual reality. Still it seems that a few basic tools – analogous to, let's say, the paper notebook and sticky note– may emerge and be widely adopted across many VR settings. We aim to discover these basic tools and shed light on how they ought to be integrated with the process of learning, including learning with teachers and peers, individual study, and the subsequent review processes.

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