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Browsing E-Lecture Libraries on Mobile Devices: A Spatial Interaction Concept

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***Abstract*—Increasingly powerful mobile devices like the Apple iPhone empower learners to watch e-lectures not only at home but also in mobile learning scenarios virtually anywhere and anytime. However, state of the art mobile video browsers do not support learners in getting an overview on and navigating between the large amounts of semantically related e-lectures, which are available in various digital libraries. We contribute a novel user interface for the mobile use of e-lectures. Leveraging a spatial navigation metaphor, it supports both linear and nonlinear interaction within a single lecture, as well as the efficient navigation within large e-lecture libraries. Evaluation results show that our e-lecture browser significantly improves the learning process and leads to significantly higher efficiency and user satisfaction.**

Keywords-mobile learning; e-lectures; video browsing; digital libraries; interaction concepts; user interface; user study

I. INTRODUCTION

The ubiquitous availability of multimedia learning material through digital libraries like for instance iTunes U [1] or OpenCourseWare [2] has paved the way for groundbreaking changes in mobile learning. Increasingly capable mobile devices like Apple's iPhone empower learners to access recorded classroom lectures (so-called e-lectures) almost anytime and anywhere. E-lectures consist of various, synchronous multimedia streams, typically an audio recording of the lecturer's talk (*audio stream*) and (probably annotated) presentation slides (*whiteboard stream*). A video of the lecturer (*video stream*) is optionally presented [3].

A recent study [4] found a shift in the usage habits of students towards using the mobile version of e-lectures. The students used the mobile versions in different situations, e.g. when commuting using public transport. The time spent on public transport has been analyzed in-depth by a further study across 11 European cities [5]. It reports that about a third of the participants spend about one hour per day commuting using public transport. Hence, this large amount of time can be used effectively with e.g. e-lectures to perform follow-up course work.

Fostering a good learning process should not only comprise the usage of individual, isolated e-lectures. Like it is common practice with textbooks or web pages: comparing and contrasting topically related lectures is highly beneficial for successful learning. By using e-lectures from different institutes or lecturers, learners are able to receive elaborate explanations for a certain problem, e.g. an alternative or more detailed description. Furthermore, several topically related lectures can be used to gain deeper insight into a specific problem domain by contrasting and integrating different perspectives.

This practice is possible nowadays due to the vast amount of e-lectures available online from various universities. However, state of the art mobile video browsers do not support the user sufficiently in these tasks, which involve the use of *multiple* e-lectures. A learner would have to (1) identify potential lectures in the digital library browser (see Fig. 1), (2) scan each lecture sequentially to check whether it really covers the desired topic and (3) note down or memorize the occurrences and correct positions within the e-lecture. Hence, it is impossible for learners to complete this task in a reasonable amount of time in a mobile setting.

The above observations let us formulate two key requirements for mobile e-lectures:

1) Mobile video browsers shall not only support learners when watching a *single* e-lecture but shall highlight the very relationships *between various* e-lectures. Hence, users will be able to learn within an interwoven web of e-lectures. As a direct consequence, browsers shall support learners in *getting an overview on* and navigating *between* topically overlapping e-lectures.

2) Learners shall be able to use this interwoven web of e-lectures efficiently on mobile devices, overcoming their limited device characteristics like small form factors.

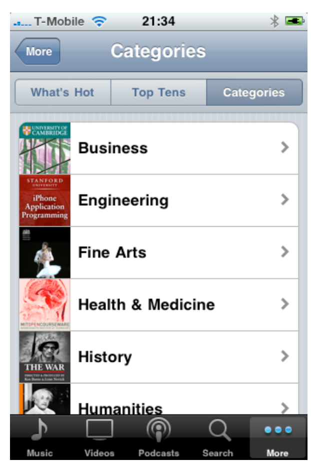

Figure 1. iTunes U digital library browser for the iPhone OS. Users can either search for lectures or choose from various categories. However, lectures can only be watched as an ordinary movie.

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Based on these requirements, we have developed an interface concept for the mobile navigation of large e-lecture libraries. This comprises two novel, spatial interaction techniques for the mobile, nonlinear interaction with multiple e-lectures. To the best of our knowledge, there exists no other approach addressing the mobile usage of multiple e-lectures. In the remainder of this paper, we first present our concept before reporting on evaluation results, which confirm that our concept significantly improves the learning process. After describing related work, we finally discuss our findings and point out potential future work.

II. Interface Concept

The main goal for our interface concept can be deduced from the requirements for mobile e-lectures formulated above. The interface shall allow for an intuitive interaction *within* and *between* e-lectures. Moreover, it shall foster awareness of e-lecture interrelationships, despite the mobile device's small screen. Due to these facts, we have utilized a simple but powerful spatial, two-dimensional metaphor (see Fig. 2). The horizontal dimension is used to browse within an e-lecture. The vertical dimension is used to navigate between topically related e-lectures by following hyperlinks between the slides. Topical relationships are expressed as hyperlinks between the lecture slides. Learners are therefore able to browse such a large conceptual space of interrelated e-lectures, although the small screen of the mobile device only shows a certain subset.

A. Horizontal Navigation: Within E-Lectures

The efficient navigation within an individual e-lecture and getting an overview on the lecture is crucial for successful learning. For instance, learners must be able to easily find and access specific parts when reviewing contents as well as to grasp the context of a particular topic in the scope of the lecture.

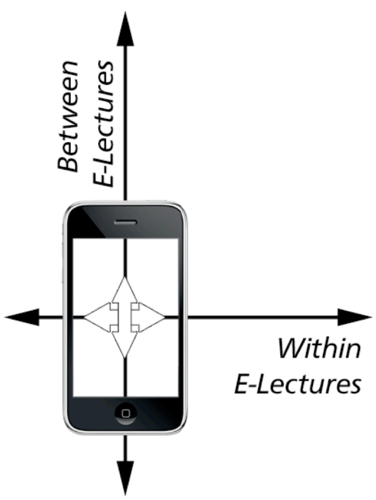

Figure 2. Spatial interaction concept: horizontal flicking browses within e-lectures, vertical flicking browses between e-lectures.

Learning this way requires

1) getting *detailed information* on the current topic,

2) easy *navigation to related information* in the context of the current topic (e.g. preceding/following topics) and

3) an *efficient overview* on the entire lecture with quick access to any of the contents.

Since in practice these three activities are highly interrelated, we offer integrated support in one single interface. Instead of the timeline-based navigation of typical video browsers, we utilize the slides as basic navigation objects. These are advantageous for two reasons: First a slide encapsulates coherent semantic content and second, it provides a good visual cue on its contents.

The interface is shown in Fig. 3. It is subdivided into two areas: current topic and overview.

Figure 3. Horizontal navigation within an e-lecture

Detailed interaction with the current topic and its context is supported in the upper part. This shows the current slide in detail. Playback of the slide recording is started either by simply rotating the device into landscape mode or by double tapping on the current slide. Moreover, learners can easily navigate to the direct context of the current slide using a gesture, which is inspired by flicking through a paper book. A horizontal flicking gesture on the slide or the video playback navigates to the preceding or following slide.

Overview navigation within the entire lecture is supported in the lower part of the interface. This shows an overview with thumbnails of all slides in a grid layout. The currently active slide is highlighted. A slide can be selected by tapping on its thumbnail. Moreover, slides can be skimmed very quickly by sliding the finger over the grid.

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B. *Vertical Navigation: Between E-Lectures*

Knowledge integration from different sources is a common task when for instance preparing a term paper. Learners need to be aware of the sources' existence, require an overview on them and need efficient access to them as well. The latter specifically involves accessing several sources within a short period of time. In terms of textbook work, learners would for instance open several related passages in a text at the same time and compare them sequentially. The same holds when using other media like e-lectures for knowledge integration. Our vertical navigation concept for topically related e-lectures supports the above tasks and is described in the following.

Our concept models topical relationships between e-lectures by binary, symmetric hyperlinks between slides. It is out of the scope of this paper how these links are created, since we focus on the navigation concept. Hyperlinks could be created automatically through multimedia information retrieval [6]. Furthermore, the user interface could be enhanced to allow learners to manually create (and share) links between slides.

Whenever an e-lecture overlaps topically with other e-lectures in the digital library (e.g. two slides cover the same topic), available hyperlinks are indicated by a small arrow in the upper right corner of the user interface (see Fig. 3). When the user flicks downwards, the interface is being scrolled downwards, revealing related e-lectures (see Fig. 4 bottom). They are horizontally aligned to provide an overview over the available related e-lectures. In this example, two interlinked e-lectures (visualized using grey boxes) contain relevant material. By tapping on one of the lectures, the interface is being scrolled down further, thereby displaying the interlinked slides of the related lecture (see Fig. 4 top). The slides can be browsed again by flicking horizontally. In turn, these can also contain topical relations to other e-lectures, which are thence visualized again with a small arrow in the upper right corner.

By aligning semantically related e-lectures vertically, the browsing history results in a vertical stack. This can be navigated by simply flicking vertically up and down

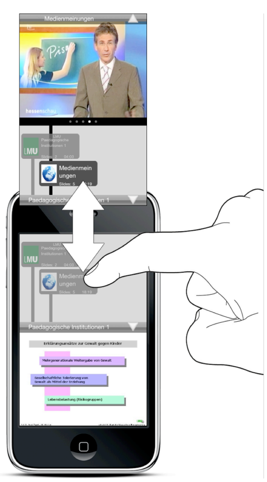

Figure 4. Vertical navigation between e-lectures.

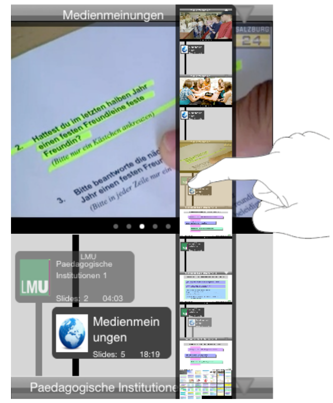

Figure 5. Visualized browsing history: The vertical navigation history is displayed as an image on top of the current video, which can be navigated by moving the finger vertically across the images.

respectively. Alternatively, to avoid repetitive flicking and to gain an overview on the browsing history, a visualization thereof can also be used for the vertical navigation as shown in Fig. 5. The continuous vertical navigation allows for a quick access to related e-lecture parts. To continue with the textbook analogy from above, this kind of navigation can be compared to aligning several relevant text passages in different textbooks vertically and switching from one to another. The possibility to flick horizontally in every vertical navigation step corresponds to flicking within related text passages contained in each of the textbooks.

The playback of an e-lecture segment can again be started by either rotating the device or double tapping a slide.

III. Evaluation

We have implemented the concept as part of an e-lecture browser for the Apple iPhone. It has been evaluated in a controlled experiment with 44 (under-)graduate students (30 male, 14 female). The students had different educational backgrounds, i.a. mathematics, pedagogy, philosophy, physics, design, psychology, business administration, medicine and computer science. Each single-user session lasted about 2 hours. The overall goal was to evaluate the influence on the learning process. We have therefore measured the effectiveness, efficiency and learnability of the e-lecture browser, as well as user satisfaction and interface attractiveness [7]. Both, time required to complete tasks (explained in the following) and usability errors thereby were measured. For each task, a different set of e-lectures was utilized to exclude any learning effects. The sessions were video-recorded and semi-structured interviews were conducted.

The experiment was subdivided into two parts (within-subject). The first one concentrated on navigating within individual e-lectures (*intra-lecture navigation*) using the horizontal dimension. The second part focused on the navigation of interrelated e-lectures (*inter-lecture navigation*), therefore adding the vertical dimension. This subdivision allowed us to assess the specific influence of each dimension on the usability and user experience goals.

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A. *Intra-lecture Navigation*

When doing follow-up course work or preparing for an exam, learners typically remember the visual representation of a particular slide or a text snippet contained within a slide, which they then use to quickly retrieve the desired part of the lecture and continue with their learning process. Analogously to this scenario, the students had to complete two visual, slide-based fact-finding tasks (*Visual 1* and *2* in Fig. 6) and one textual fact-finding task (*Textual* in Fig. 6).

The students were presented two different user interfaces: (1) an enhanced standard iPhone media player as baseline (*Baseline* in Fig. 6), providing additional buttons to switch back and forth between slides and (2) our e-lecture browser as shown in Fig. 2 without the possibility of inter-lecture navigation (*1D-Nav* in Fig. 6). The learners were asked to complete the tasks with each user interface.

The results show, that our spatial concept allows learners to work significantly more efficiently and therefore more

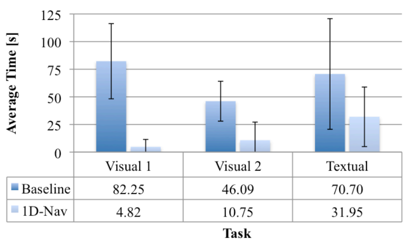

Figure 6. Average time per task for intra-lecture navigation

easily with e-lectures (see Fig. 6). They were able to complete all three tasks significantly faster ($p < 0.001$) and committed about 60% less usability errors (significant with $p < 0.01$). The students stated that our browser supports their visual orientation and navigation. The concept was perceived as far more attractive (with an average score of 5) than the standard iPhone player (with a score of 2.5 on a 7-point Likert scale). The students commented on our grid-based browser as being "practical", "intuitive" and "perfectly suited for e-lecture browsing".

B. *Inter-lecture Navigation*

In order to evaluate how learners navigate within a set of interrelated e-lectures, we asked them to complete two different tasks. First, a more complex fact-finding task (Fact-finding in Fig. 7) comprising visual, as well as textual fact-finding tasks across several e-lectures (N=7). The second task aimed at investigating the efficiency of knowledge integration tasks. This is for instance the case when learners want to gain additional insight into a topic by considering supplementary sources. In our task, the students were asked to integrate knowledge contained in different e-lectures (N=3) for a specific topic.

The students were presented two different user interfaces. First, an enhanced standard iPhone media player, which allows switching forth and back between slides. Moreover, it displays topical relationships as textual hyperlinks on the slides (*Baseline* in Fig. 7). Second, the participants were

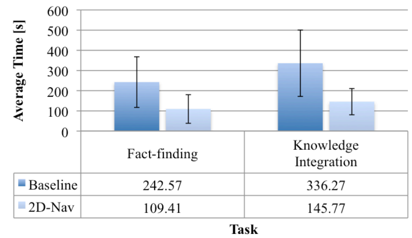

Figure 7. Average time per task for inter-lecture navigation

asked to utilize our video browser with both, horizontal and vertical navigation capabilities (*2D-Nav* in Fig. 7). The learners were asked to complete the tasks with each user interface. To exclude any learning effects, we used a between-subject design for the second task.

The students worked significantly more efficient using our spatial e-lecture browser. In both tasks, they were significantly faster ($p < 0.001$) using our video browser as shown in Fig. 7. These results confirm that our user interface supports the user's orientation when navigating across multiple e-lectures. Moreover, statements in the interviews showed that the two-dimensional browsing metaphor fosters the learners' awareness of inter-related e-lectures. The participants committed about 65% less usability errors using our e-lecture browser than using the baseline player (significant with $p < 0.001$). Finally, our e-lecture browser was perceived as far more attractive with an average score of 5.5 than the enhanced iPhone media player with an average score of 2.5 on a 7-point Likert scale.

In the interviews, the students commented on our spatial concept as "clearly laid out" and they remarked that the vertical alignment of the related e-lectures intensifies the visual relationship between the lectures. This lets us draw the conclusion that learners are more engaged in their learning process using our interaction concept.

IV. RELATED WORK

We are not aware of any approach focusing on the mobile interaction with *multiple* e-lectures and in particular fulfilling the requirements for mobile e-lectures formulated in Section 1. However, extensive research has been conducted targeting e-lecture browsing on desktop computers. There are also several approaches, which try to support users when browsing *individual* videos on mobile devices. We therefore compare both, desktop e-lecture browsers and mobile video browsers to our concept and discuss their relevance for mobile e-lectures.

A. *Browsing E-Lectures on Desktop Computers*

There exist various e-lecture browsers for desktop computers [8, 9, 10]. They all support browsing of individual lectures using a time-slider, present lecture slides visually and allow users to switch forth and back between slides. Due to the required screen space, these approaches cannot be easily transferred to mobile devices.

Several advanced search and navigation concepts have been presented that go beyond this standard. Mertens et al. [11] enhanced a time- and slide-based e-lecture browser for

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desktop computers with hypermedia navigation concepts (e.g. backtracking, bookmarks and footprints) for individual e-lectures. In OpenCourseWare [2], an automatically generated transcription of the lecturer's talk allows students to perform full text queries to navigate within a lecture. This concept has been extended by Linckels et al. [12] in an e-librarian service, which is able to answer students' questions posed in natural language. The answer is matched through an ontology and returned in terms of multimedia learning objects. However, this ontology is static and needs to be created per lecture in advance. While these are very powerful concepts for navigating within lectures, they are not well suited for mobile devices. It is tedious to enter complete questions on the small keyboard of a mobile device and the mobile setting is typically too noisy to achieve robust results using voice input.

Somewhat similar to our work, Altman et al. [13] present a visual navigation concept. Semantically meaningful structures from a lecture are extracted to be presented as a graph. This graph has the advantage of further abstracting from the linear structure of the lecture. However, when the complex graph of a longer lecture is displayed on the small screen of a mobile display, the user is likely to lose orientation. In contrast, we have a simpler spatial model, which nevertheless is powerful and in particular, remains clear also on small displays.

B. *Mobile Browsing of Individual Videos*

Hürst et al. [14] have developed various interfaces for the mobile browsing of individual videos. Most notably, the MobileZoomSlider allows users to skim quickly through continuous video streams by replacing the original time-slider with a rubber band metaphor. The rubber band is connected to an alternative time-slider. By spanning the band, the playback speed is adjusted adaptively. This approach supports the browsing of individual videos when being replayed continuously like a movie. However, it does not support selective interaction like it is common practice when e.g. preparing for an exam.

Kamvar et al. developed the MiniMedia surfer [15], a mobile browser for small video segments. The browser supports keyword queries and users explore query results through key frames. The navigation completely relies on the designated keywords for each video segment. This is a major issue when trying to get an overview on a set of videos (and particularly e-lectures) without knowing what to look for.

V. Conclusion

In this paper, we contribute the first user interface concept for browsing lectures on mobile devices that efficiently supports both, navigating within single lectures and between topically related e-lectures contained in digital libraries. The evaluation in a controlled experiment with 44 students shows that our e-lecture browser significantly improves the learning process by (1) supporting the user's orientation, (2) fostering awareness of interrelations and (3) enabling learners to complete complex tasks significantly faster while committing significantly less usability errors than using a state of the art mobile video browser. Both, the horizontal and the vertical navigation were perceived as key concepts, improving the browser's attractiveness and usability. In order to further validate these results, we plan to conduct a long-term field study of our e-lecture browser.

We have successfully shown that even complex information spaces like highly interlinked digital libraries can be presented on devices with restricted form factors in such a manner that learners are able to build up a valid mental model thereof. The key for this achievement is the reduction in complexity by employing a simple but powerful spatial navigation metaphor, which fosters the learners' orientation, instead of reducing complexity by removing content. This principle should be applied in further mobile learning scenarios to empower learners to efficiently deal with complex contents on mobile devices.

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