SlidAR: Towards using AR in Education

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Abstract
Applying Augmented Reality in education is being explored by many scientists. Therefore, we augment digital slides of lectures in higher education. We implemented a web server application, which allows professors to create their own AR slides. We also developed a mobile app for students to scan the slides and view the augmentation in lectures or learning sessions. To assess the usability of our system, we conducted a study with fifteen students and two professors. Students' feedback indicated that our AR app could be integrated into education. Professors, on the other hand, reported improvement suggestions. However, both groups supported applying the system in real lectures.

CCS Concepts
•**Human-centered computing** → **Mixed / augmented reality;** •**Applied computing** → *Interactive learning environments;*

Author Keywords
Augmented Reality; Education.

Introduction
Smartphones and electronic devices have become ubiquitous, which facilitated Augmented Reality (AR) to be within the reach of many users [23]. Built-in cameras and constant Internet access can enable sophisticated AR apps

running on these devices. Thus, AR was explored across many fields including medicine, maintenance, robot simulation, entertainment, and military [4]. Following the Cognitive Theory of Multimedia Learning (CTML) [20], the educational context can also benefit from AR due to the rich visual content. While AR has been applied in the learning context before, research focused on educating for physics [13], mathematics [16], chemistry [5], or electrical engineering [19].

In this paper, we present *SlidAR*, a system to augment lectures with AR content. For this, we used lecture slides as markers. The *SlidAR* system recognizes the slides and provides pre-defined AR content to the user. We report on a first evaluation showing the overall usability of our system.

Related Work

AR offers new learning opportunities [25] and can promote collaborative and autonomous learning [19]. Dede stated that applying AR in informal learning environments, where students are voluntarily self-learning outside of the traditional classroom, shows the most promising results, in terms of students' engagement [9].

Considering the potential positive effect AR might have on children in informal learning environments, Cang et al. studied the effects of using an AR museum guide in comparison to the normal audio guide and to no guide at all [7]. Results showed that using AR helped participants appreciate the museum paintings more. Eiksund also developed a prototype of a children's AR storybook and evaluated how children interact with it [10]. Results showed that participants who used the AR storybook, rather than the traditional storybook, were able to solve more tasks. Feedback also elaborated that children expressed positive emotions while using the AR storybook. A third example of using AR in informal learning environments was the AR mobile app *MakeAR*, which was implemented by Oberhuber et al. It provided children with methods to create their own treasure hunts using AR [22]. Results showed, that applying AR in education can enhance creativity, promote self-learning, and create a better learning environment for young children. Sommerauer and Müller, confirming the positive results of using AR for educational purposes [23]. AR was used in a mathematical exhibition. Findings showed that visitors gained more knowledge from augmented exhibits than from non-augmented ones.

Freitas and Campos implemented *SMART: SysteM of Augmented Reality for Teaching* a system for child education [11]. The system was evaluated with primary school students. Results showed that young children were motivated to learn second-grade-level concepts such as the types of animals and the means of transportation. Medicherla et al. also implemented an AR application, using *SMART*, to teach the solar system to children in schools [21]. Findings showed that AR improved children's spacial skills and understanding of the solar system.

AR in the field of education can improve the students' performance, and facilitate the psychological satisfaction for learners[12]. They related the psychological satisfaction of a learner to the improvement of his or her educational experience and performance. Further, AR can encourage students' self-learning. AR increases the students' psychological feeling of satisfaction and it positively influences their learning experience[13]. Further, AR also helped students gain more conceptual and practical knowledge.

Not only can the application of AR in education improve the psychological side of learners, students with physical disabilities can benefit AR learning environments [3].

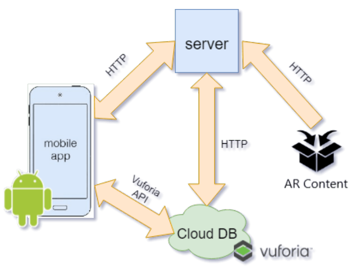

Figure 1: SlidAR Architecure: AR content together with lecture slides can be uploaded to the server. The mobile app retrieves the content in order to display on top of slides. To link slides to AR content and to detect slides that can be augmented the Vuforia API and Cloud DB is used [14, 24].

Figure 2: The web application GUI. A list of already created AR slides is displayed in the middle. Two buttons are shown as well: one to create a new AR slide, and the other to delete any chosen slides.

Arvanitis et al. used an interactive educational system to introduce abstract concepts like airflow, magnetic fields and force variables to students with physical challenges. The interactive educational system enhanced the learning experience of the disabled students.

AR in education is not limited to child education. According to Karsten et al., applying AR in education should not be a replacement for traditional known teaching methods. Instead, it should be used as a helpful additional method, in combination with the conventional ones [15]. For example, Kaufmann and Schmalsteig developed a 3D geometric construction tool called Construct3D [16]. It improved the students’ spatial skills. Aliev et al. also created a 3D AR interactive textbook for mechanical engineering students [1]. As a result, AR added practical experiences to the theoretical knowledge of university students. Moreover, Alrashidi et al. conducted a study, to investigate if AR improves the practical educational experience of engineering students [2]. AR was used to provide easy steps to assemble the hardware components of a robot, and also provide extra information with each step, thus improving the overall education of the students.

Another study was conducted by Magnenat et al., who used the educational robot *Thymo*, to teach Computer Science (CS) [18]. They argued that Computer Science (CS) education can benefit from visualizing abstract concepts. In a second study, they examined the effects of using AR with the educational robot *Thymo*, to provide visual real-time feedback to students[17]. They examined how the addition of AR could help teach students the concept of event handling of CS. Findings showed that AR provided a significant enhancement in learning and understanding the event handling concept of CS.

Based on the literature AR can improve spatial knowledge and encouraged collaborative learning. It promoted both self-learning, as well as experimental learning. Further, it helped students gain practical skills and fostered problem-solving skills. It also increased the learners’ psychological satisfaction. Leveraging its special feature, which is the interaction with digital objects embedded into the real world, AR is considered to have great potential in science education [6, 8, 25]. However, little is known about the effects of using AR in lectures of higher education.

System

To provide students AR enriched slides and to facilitate the creation of AR slides for the professors we developed a system that realized both. It consists of a web server application for managing AR slides and an Android app for scanning and augmenting slides. Both the mobile app and the server use the Vuforia API and Cloud DB.

SlideAR Architecture

The architecture of *SlidAR* is shown in Figure 1. It consists of a web server to which slides and AR content is uploaded by the professors. Therefore a web-based control panel is used to link AR content to a specific slide (see Figure 2). Further, the control panel allows to add and delete AR content to specific slides. To recognize slides as anchors for AR content the server uses the Vuforia API and the Vuforia Cloud DB. A professor would upload a slide that should be augmented and the corresponding AR content. The server uses the Vuforia API to create a linkage between slide and AR content. Later, this can be used by the mobile app for recognizing slides as augment-able and then display the linked AR content.

When a student uses the mobile Android app (see Figure 3) to scan slides the AR content and the linkage between AR

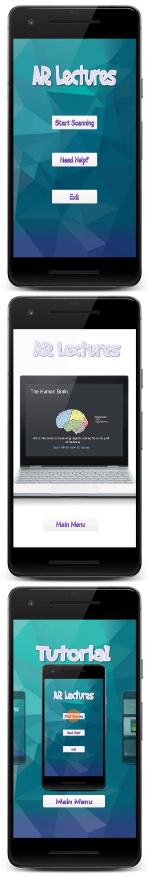

Figure 3: The three different scenes of the Android app a) The main menu scene. b) The lecture scanning mode: In this mode the student can scan slides to display AR content. c) A guide on how to use the app is provided through static screen shots.

content and slide is requested from the server. Afterward, the app queries the Vuforia Cloud DB to recognize slides as targets for displaying the corresponding AR content. Therefore the app opens the phone's main camera and scans the real world environment until it recognizes a slide that was linked to AR content. The scanned environment is compared with the previously uploaded slides using the Vuforia Cloud DB. When a matching result is found, the app tracks the slide and displays the AR content.

Study

We conducted a study to assess the usability of *SlidAR*. Therefore, we recruited fifteen university students to participate in our study: four females and eleven males (aged M=26.27, SD=3.75). All the students were studying subjects, related to CS, for example, Artificial Intelligence (AI) - System Engineering (SE), Network and SE, Human-Computer Interaction (HCI), Business Informatics (BI), Electrical Engineering, or Applied CS. We also collected feedback from two male professors, who teach Computer Science and Visualization. One professor had nine years of teaching experience the other had thirty. All participants signed a consent form first and filled a participant form before starting the experiment. Then we introduced them to *SlidAR*. The students sit down and use the system in a quiet room with only the experimenter being present.

The students were presented with slides, which they could augment using the mobile app installed on an Android device we provided. For the slides, we augmented five slides of a BCI lecture with AR content, related to the shown topics. Whenever indicated on the slide that there's an augmentation, the student could view the AR content by placing their phone in front of the slide.

The professors were presented with the same slides, which they could augment using our web server. We provided five AR objects, which were displayed on a second screen. The professors could choose to link an object to a specific slide. Therefore they used the web interface of the *SlidAR* server.

Finally, we conducted a semi-structured interview to collect the participants' impression and feedback. The interview questions were asked according to the participant's perspective; the students were asked to answer if they could imagine using our system while studying, while professors were asked if they imagine using it to teach their subject.

Results

To assess the general impression of students and professors, we interviewed them and collected their feedback. Findings of these semi-structured interviews provided insight on the usability of our system, as well as suggestions for future improvements.

Students Feedback

The semi-structured interview consisted of eleven questions. First, we examined the methods students use for education. All students reported that they used slides for learning. Out of the fifteen students, three students stated that they only used slides for repetition and not to learn new topics. Four out of fifteen students reported that they rely on lectures and self-written notes, to understand new concepts, while seven students reported, they also used videos for learning. These seven students stated that videos allow them to learn at their own pace, offering them the option to pause or go back. Moreover, they explained that videos visualize the concepts. Four of them added that they used textbooks as well.

We also collected the participants' opinion on the benefits of our AR Lectures system. On a scale from 1 to 5, students rated the usefulness of our AR Lectures system. More than half of the students agreed, that the AR Lectures system was useful or very useful: seven out of the fifteen students rated it 4 and three students rated it 5. Out of these ten students, six reported that the system was useful because the AR content could display more information in addition to the slides. Four students agreed that augmenting slides would make lectures more interactive, and therefore more appealing to them. Moreover, four other students found our system innovative and interesting. However, while ten students rated our AR Lectures system as useful, four students were neutral (rating: 3) and one student rated it as not useful (rating: 2). According to three of these five students, augmenting slides was not always worth it and its usefulness would heavily depend on the topic presented in the lecture. Moreover, two students also explained that the excessive use of AR slides would be annoying to them, for example, if every slide of a lecture was augmented.

Furthermore, all students agreed that *SlidAR* helped them understand the sample slides better. Out of the fifteen students, five students reported that they enjoyed the animation and lifelike feature of the AR content. Four students stated that the AR content provided additional information. Four more students also indicated that visualized concepts through AR content helped them to understand the slides better. One participant explained, whenever the concept depended on the imagination, then AR would definitely help.

All students agreed that in their opinion *SlidAR* would be beneficial for education in general. They reported, that it would motivate students in schools and also in higher education, and Computer Science education in specific. They stated, that it might become a new trending tool, in addition to the current teaching methods.

We also asked students to rate *SlidAR* according to how distracting it was. On a scale from 1 to 5, seven students rated the app was not distracting at all (rating 1) and four students rated it as not distracting (rating 2). Among these eleven students, six explained that the user was always given the choice when to use the app. Out of the fifteen students, two students argued it was distracting (rating 4), and one rated it as very distracting (rating 5). These three students explained that reading from different display sizes split their focus. The one remaining student refused to rate the app. Further, nine students found it easy to hold the mobile device while using the app, the other six students said that it would be tiresome to hold it for longer times. Out of the nine students, who did not find it tiresome to hold the mobile three students argued that they already use their mobile devices during lectures for personal uses, so using them to run the app instead of other things could have a positive impact on them.

Further, all students, except one, stated that they like to see the app can usable in real lectures. Three out of these fourteen students stated that they would like to see this app offered for home learning sessions. The students agreed that the app made the slides more interesting, more motivating, and more interactive. Other students explained, the app would visualize the concepts better and helps to understand the topic. One participant explained, she disapproved to imagine during lectures, so AR would help to visualize the unseen. Also, three students suggested using AR glasses to display the augmentation.

Professors Feedback

The professors reported that they used slides as part of their teaching and listed further methods they used, like handwritten notes, drawings, and animations. While the first professor rated *SlidAR* as not that useful (rating 2), the second professor was neutral (rating 3). They explained, it would be only beneficial in learning in special cases, especially when 3D models and animations are required. The first professor agreed that the AR Lectures system could help professors teach areas which require 3D modeling, like Scientific Visualization and Computer Graphics, while the second professor could not imagine examples from his teaching area that could benefit from using AR. Both said that other fields could benefit from *SlidAR* like Psychology, Social Science, and Medicine. The first professor suggested an option to create and place the AR content in a simple straightforward manner. Therefore, primitive objects should be provided by the system that he can use to create AR content. Moreover, both professors hoped to see this AR Lectures system used in real lectures and supported the conduction of further studies to evaluate its effects on students' learning.

Discussion

In our study, we observed a generally positive response from the students. All reported that they used slides to learn. This indicates that our system could be integrated into the current learning process. Although nine students were not personally motivated to learn more about the topic presented in the sample slides, all students estimated that *SlidAR* might be motivating in early and higher education. Students explained that the app displayed additional information in AR. That made the slides more interactive and interesting. This supports the literature findings that AR is considered to have great potential in science education because of its interactive feature [6, 8, 25]. The students also expressed some concerns about our AR Lectures system. They reported that the usefulness of *SlidAR* heavily relied on the topic and the AR content. Another concern was the excessive use of AR in lectures. Students stated that it might lead to distractions.

The professors expressed that they would like to have a simple AR content creation tool, which they could use to control their AR content. Since the current implementation of the AR system relies on the manual creation of AR content, we suggest automating the process of creating AR content and adding interaction scripts to it. Currently, the content is created using Unity3D. While both professors could not imagine using *SlidAR* in their own fields, they suggested some fields where it could be useful e.g. Computer Graphics, Medicine, Psychology, Computer Visualization, and Social Science. Furthermore, they supported the use of the system in real lectures. Finally, seven students rated *SlidAR* as useful and three students as very useful, and fourteen students hoped to see it applied in education.

Conclusion

In this paper, we present *SlidAR*, a system to augment lecture slides with AR content. We conducted a user study with students and professors and showed that the *SlideAR* is capable of supporting both groups.

In future work, we plan to investigate the effects of applying the AR Lectures system in higher education, especially its effect on the students' understanding, and on the student's motivation and involvement during lectures. While there are many different prototypes of using AR in lectures, the actual effect of AR on the students performance yet needs to be investigated. For this, *SlidAR* provides the first step in tackling this important research question.

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