AR postcards as a learning tool in Computer Graphics

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Abstract

Preserving cultural heritage is a vital part of preserving the history of a country. Computer Graphics students created Augmented Reality (AR) postcards with 3D models of Bosnia and Herzegovina (BH) cultural heritage objects. They added various Points of Interest (POIs) related to the objects with different multimedia content. The content in the app is just a small glimpse into the vast history of every single object picked, purposely designed to be easily digested by users of all ages. These postcards were integrated into a single app with the goal to present information about cultural heritage buildings in a new, interesting and easily accessible way.

In this paper, we describe the teaching methodology and resulting AR application. Through the user eXperience evaluation study, we checked if this approach improves the overall experience of learning about cultural heritage objects. The results of this evaluation will contribute to the development of future AR applications for cultural heritage.

Keywords: Computer Graphics education, Augmented Reality, digital heritage

1 Introduction

Computer Graphics (CG) is a very demanding field for education as it consists of many very important and diverse sub-fields. Starting from so-called "hardcore" CG with algorithms for conversion of coordinate systems, matrix transformations, clipping, shading, illumination, and rendering, it expanded to computer vision, computer animation, multimedia, and mixed reality. It is very difficult to present all these notions and important applications of CG within the basic undergraduate course. Therefore teachers need to make certain compromises. At the Faculty of Electrical Engineering, University of Sarajevo, computer graphics is studied in the Computer Science department. Students are offered a basic CG course at the Bachelor level and two elective courses at the Masters level. A common feature of all these courses is that they are more oriented to CG applications and less to graphics algorithms and programming. The reason behind such a decision is that students of this Department have plenty of programming courses to attend and not much opportunity to learn skills such as 3D modeling and animation and Virtual/Augmented Reality applications development. Another particularity of teaching CG at the University of Sarajevo is offering students the basics of graphic design, so their visual presentations and user interfaces (UI) would fulfill the expectations of their users without the necessity to include graphics designers in the software development team.

The main contribution of this paper is the novel approach to teaching computer graphics, which involves adding the artistic aspect of the topic and offering students to obtain application development skills instead of sole graphics programming. In that terms, we present the teaching methodology of a basic Computer Graphics course at the undergraduate level with particular emphasis on an Augmented Reality lab project that was later turned into a digital cultural heritage application. In that project, students were requested to design and implement AR postcards with the most interesting BH cultural monuments. The paper structure is as follows: in the Related work Section we describe the relationship between CG education and AR applications for cultural heritage, Section 3 presents the structure and teaching methodology of the course we describe, and Section 4 shows how the students are being marked. Section 5 describes the AR lab project workflow, while Section 6 shows the novelty of our teaching and explains how it can be used for creating a digital cultural heritage application. We also present results of preliminary user experience evaluation to show the appre-

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ciation of created application by different users. In the last Section, we offer our conclusions and lessons learned.

2 Related work

While the use of novel technologies serves as a catalyst for student engagement in education [6], it is equally important to evaluate the perspective of educators. The survey [13] reveals that teachers are open to the idea of incorporating AR tools into the classroom and are motivated to expand their skills through continued professional development and training sessions. Despite limited prior experience with 3D modeling, the teachers expressed a strong desire to learn and even to contribute to the creation of new AR-based learning tools.

This is not present only in the AR field but many others in computer graphics, as teaching methods can be very diverse. As authors [11] point out: "Computer graphics is often regarded an exciting and enjoyable subject due to it combining technology, art and creativity". This is why many teachers have different approaches to teaching methods and even some smaller changes can be quite refreshing [14]. However, it is also important to follow what others are learning in computer graphics and fill the gaps of so large area as authors show in [2]. Further research shows that thematic AR and VR courses are still rare and fragmented [8] showing us that more good practice is needed in this area.

Since the past decade, AR applications were utilized for cultural heritage preservation. The most active countries in the field of AR use in cultural heritage are Italy, Greece, Spain and the UK [3].

Authors in [12] present an application that demonstrates the value of digital heritage in tourism. Here, the AR application exploits the concept of gamification in order to aid the process of learning history.

Author in [4] presents an AR application in an educational context for a design course. The app is found to aid students in concentrating, self-learning, and also to raise students' confidence.

Additionally, AR can provide more interactive and cooperative communication ways between students [9].

The authors compared mobile learning by means of an AR application on a tablet used in real fieldwork learning to traditional e-learning that takes place in a classroom with a regular desktop computer in using heritage elements of the city Santiago of Chile in [7]. The study found that the mobile learning process significantly enhanced educational outcomes.

In [1] the focus of the mobile AR multi-user game application is historical knowledge gain, and the application was used both in an indoor and outdoor setting.

3 Computer Graphics Course at the University of Sarajevo

Every student in their third year of the Bachelor program at the Faculty of Electrical Engineering, University of Sarajevo, developed an AR application as part of a Computer Graphics Course supervised by graduate teaching assistants. The goal of the course is for students to acquire theoretical and practical knowledge of the basics of computer graphics, such as raster and vector graphics, coordinate systems, geometric transformations, perspective projection, clipping, color theory, color systems, 3D modeling, scene illumination, texture mapping, shading and rendering, UI design and evaluation, and augmented reality.

The course was delivered over one semester and consisted of lectures (2 hours per week) and tutorials (45 minutes per week). Lectures have covered the following topics: raster and vector graphics, color theory and graphics design basics, 3D modeling techniques, basics of Human-Computer Interaction and usability, shading, clipping, anti-aliasing, basics of Unity 3D scripting, 3D scene illumination algorithms, and techniques, Virtual and Augmented Reality and Virtual Reality video.

In order to be able to create the requested lab projects students were offered the following tutorials presented by a graduate teaching assistant and had corresponding written materials for them:

1. Introduction to Blender (getting started with blender: user interface, creating simple objects)
2. Object modeling (using modifiers, proportional editing, tools for mesh editing)
3. Materials and texture mapping (creating new materials, using various built-in materials, shading editor, using an image as texture and UV editing, adding multiple materials to one object)
4. Lighting and rendering (using different built-in light sources, three-point lighting rule, emission shader, adding ambiance with High-Resolution Light (HDR) probes, camera settings, and using cycles as render engine)
5. Preparation of objects for exporting (simplification of objects using collapse, unsubdivide and planar modifiers)
6. Introduction to Unity (getting started with Unity: importing .fbx object to Unity, user interface, game, and scene view)
7. AR development (setting up Vuforia engine, image recognition)
8. Scripting in Unity (using colliders, adding multimedia content on object click such as 3D text, images and image gallery and video)

9. UI in Unity (creating canvas: adding buttons, panels, images)

10. Particle systems

4 Exams and marking methods

Students were marked during the semester on incremental work on their projects. Each mark for 5 separate assignments represented 2% of their final grade and was given for: a document describing the plan of project development, renders of the 3D object, successful image recognition, POIs and scripting, and UI layout and controls.

The final version of every student project went through a detailed revision that consisted of reviewing: the renders of the main object (10%), the model appearance after importing to Unity (5%), POIs and scripting (10%), UI (5%), application layout, ease of use, readability, color harmony, and creativity (10%). This final revision represented 40% of the final grade.

The exams consisted of multiple-choice questions about theoretical and practical knowledge obtained during the course. We organized two partial exams (20% each) and a final exam (40%). Students could pass the course if they obtained at least half of the maximum points at both partial exams or the final exam. They got two opportunities for remedial exams.

Marking creativity is particular for CG courses in our University, while other courses are marked through the standard computer science marking schemes. We introduced it to differentiate extremely talented and dedicated students from those who just learned the requested techniques and skills without new ideas, just to get a good mark. Creative students showed that such thinking yields better and more visually appealing results, which, in the end, sell the software product on the market and make it different from other similar products. Students had the freedom of choosing which POIs to use and the multimedia content that was linked to the object, as well as choosing to add elements to the object surroundings which were not a requirement. Additionally, they had complete creative liberty to choose the color, style, scale, layout, and function of every UI element. There were no predefined visual elements for the student applications. After the best projects were chosen to be integrated into the BH Heritage AR application the UI layout of the individual student projects was made uniform throughout the application.

5 AR lab project

At the beginning of the course, students chose an object which represents a cultural heritage site in Bosnia and Herzegovina. Following the selection process, students wrote detailed documents about their projects which included:

- basic information and photo documentation about the chosen object
- the description of points of interest (POI) objects that are thematically associated with the main object, and the multimedia content that is to be displayed when POI is clicked
- application design plan which includes a layout mockup

The students began the project by creating the 3D model of the chosen object, after which they added materials and textures, lighting, and finally made rendering images of the object from different angles in Blender. After the modeling phase, the object was exported in the .fbx format and imported to Unity. The next phase was adding image recognition using the Vuforia engine which included creating a postcard of the object, and adding it as an image target that would display the 3D object model after being scanned. The phase that followed consisted of adding POI objects and scripting the behavior of displaying the defined multimedia contents on object click. The final phase was creating the application UI, consisting of the basic information about the cultural heritage object, help and exit buttons.

The students were supervised by graduate teaching assistants each week in the form of laboratory sessions during which they showed their progress and presented problems and difficulties they encountered.

The goal of the students' projects was to create an AR application about a cultural heritage object that presents information about the object in a new, interesting and easily accessible way.

6 BH heritage AR application

Interaction methods in AR play a crucial role in making this experience possible, and there are several ways in which AR can be made interactive.

Touch and Gesture-Based Interaction

One of the most straightforward interaction methods in AR is touch and gesture-based interaction. This type of interaction involves using touch and gestures on a device, such as a tablet or smartphone, to control and interact with digital objects in the physical world. It can be a single-touch or multi-touch interaction [10]. This type of interaction is intuitive and can be especially useful for users who are not familiar with other types of input methods, such as a keyboard or mouse.

Voice-Based Interaction

Another popular interaction method in AR is voice-based interaction. This method allows users to interact

with digital objects using voice commands. Voice-based interaction can be especially useful for hands-free scenarios or when users are unable to physically touch their devices. Voice-based interaction can also be more natural and intuitive than touch or gesture-based interaction, as users can simply use their voice to control the AR experience.

Image and Object Recognition-Based Interaction

Image and object recognition-based interaction is another method oftentimes used in AR applications. This type of interaction involves using a device's camera to recognize images or objects in the physical world. Once an image or object is recognized, the device can display digital information or objects associated with it, allowing for an interactive experience [5]. This type of interaction is useful for applications such as product labeling, where digital information about a product can be displayed when the camera recognizes the product's label.

Spatial Mapping and Tracking

This type of interaction involves creating a digital representation of the physical environment, which can then be used to place and track digital objects in the real world. Spatial mapping and tracking allow for a more seamless AR experience, as digital objects can be placed in the real world and remain in place even as the user moves.

Motion Control Interaction

This type of interaction involves using the motion of the device, such as tilting or shaking, to control and interact with digital objects in the physical world. Motion control interaction can be especially useful for games and other interactive experiences that require physical movement.

These interaction models can also be combined to create a more seamless and engaging experience. This approach is much more common as it allows for more creativity and a better user experience. Our application was created in a similar way combining some of the known models into a fully structured application.

6.1 Application description

The application is available in two languages, Bosnian and English so that it can be used by locals and foreigners alike. After choosing the language, the user is presented with an interactive map of Bosnia and Herzegovina as shown in Figure 1, which showcases various objects of interest. Each object is represented by a photo and its name, allowing the user to obtain a visual and written overview of the object. The map also visually presents the various locations of the cultural heritage objects throughout Bosnia and Herzegovina.

Figure 1: Interactive map of Bosnia and Herzegovina

The user can then interact with the map by clicking on the individual objects, providing them with a more in-depth experience. By clicking on the object, the user is taken to a tracking screen, where they can use AR technology to scan an image called AR postcard related to the object (Figure 2) that the user obtained by downloading the postcard from the free link online and printing it.

Figure 2: AR postcard related to the chosen object (free to download)

This allows the user to experience an immersive and interactive view of the object, as shown in Figure 3, enhancing their overall understanding and appreciation of the object by seeing it in full, from every angle, which is sometimes hard to do on-site.

The touch and gesture-based interaction method is utilized with the POI objects by showing related multimedia content after the user clicks on the POI. POIs that are associated with objects, along with their accompanying multimedia content, provide additional and detailed information about them by utilizing the touch and gesture-based interaction method. When the users click on a specific POI, they are presented with the corresponding multimedia content, such as images, videos, or audio content (Figure 4), that provides further information and insight about the object. This enhances the overall understanding and

Figure 3: User view of the object after scanning the corresponding AR postcard

appreciation of the object, as well as offers a more comprehensive experience.

The application features a Help button, which upon acti-

Figure 4: Display of image as the linked multimedia content to the specific POI

vation, displays an image of POIs related to the object and the description of which multimedia content will be shown on click (Figure 5). This allows the user to easily navigate and understand the information available within the application.

Additionally, the application has an Information button

Figure 5: Display of POI images and description of multimedia content shown after clicking the help button

that, when selected, presents the user with basic information regarding the object and the students who developed the application. This allows the user to quickly and easily access a general overview and background of the object, thereby enhancing their overall understanding and appreciation of the object, as well as learning about the individuals behind the creation of the application.

6.2 User experience evaluation

To check if this approach improves the overall experience of learning about cultural heritage objects, we conducted a User eXperience evaluation study. The results of this evaluation will contribute to the development of AR applications for cultural heritage preservation by determining which introduced elements are beneficial and which can be discarded or changed. Interaction methods we used in this application were a mix of Touch and Gesture-Based interaction since users are navigating the application on their mobile phones touch screen and Image and Object Recognition with Motion Control interaction. Users are able to see the object on the screen and even walk around it while it is being tracked with the camera so we could track the reaction of the users and how do they navigate the application itself. The research question of our user experience evaluation was the following:
Does the BH Heritage AR application increase the overall experience of learning about cultural heritage buildings?
The experiment included 17 participants engaged by invitation, all of which were BH citizens. Subjects were invited with balanced demographic features in mind, regarding gender, IT background, and hardware possession. Immediately after evaluating the application, participants were invited to fill out the questionnaire. The questionnaire was organized in three sections:

- Introduction, containing questions related to demographic data
- Section dedicated to measuring (1) the increase in cultural heritage knowledge, (2) the benefits of added content, and (3) application intuitivity.
- Additional comments and critiques regarding their evaluation.

The measurement of the variables of interest was performed using a 5-point Likert scale with the following structure: 2 items for the increase in cultural heritage knowledge, 3 items for experience, and one item for application intuitivity.

The results of the evaluation are presented in Table 1, with an average value and standard deviation per each question: Regarding the measurement of our ultimate goal, user experience, we hypothesized that users would have an overall more immersive experience with the application and would have an easy time learning information about various cultural heritage sites, with the intuitive UI in the application. Therefore, the expected outcomes were high values for Increase in cultural heritage Knowledge, Benefits of Added content, and Application Intuitivity.

		Avg.	St. dev.
K1	On a scale of 1-5, rate your knowledge about the chosen cultural heritage object before using the app	2.88	0.99
K2	On a scale of 1-5, rate your knowledge about the chosen cultural heritage object after using the app	4.41	0.79
A1	I think that POIs contribute to the interest of the application and individual objects	4.71	0.59
A2	I think that the info button helped in learning new information about the object	4.71	0.59
A3	I think that the help button helped in easier determination of POIs and their related multimedia content	4.88	0.33
I1	I think that working in the application was intuitive	4.82	0.39

Table 1: Questionnaire structure and overview of statistical measures. Questions related to the Increase in CH Knowledge are marked by Kx, questions related to the benefits of Added content are marked by Ax and questions related to app Intuitivity are marked with Ix. The responses were conveyed based on a 5-point Likert scale ranging from strongly negative to strongly positive.

The results strongly indicate that the use of the BH Heritage AR application increases the overall experience of learning about cultural heritage objects by immersing users with added content and an easy-to-use interface.

The results of this experiment indicate that the utilization of an AR application with supplementary multimedia content and a user-friendly interface enhances the learning experience of its users. Additionally, it is evident that all the introduced elements to the BH Heritage AR application enhance and are beneficial to the overall user experience. The POIs contributed to the interest of the application and individual objects by providing users with a variety of ways in which to interact with the object, be it by scrolling through a gallery of pictures, reading a text about objects, prominent figures, and historical events linked to the main object, seeing videos about the object or hearing related audio content. The information button further aided in the learning of new information about the objects by providing them in concise, easily understood segments. And finally, the help button helped in easier determining POIs and their related multimedia content by providing a clear visual aid seen in Figure 5.

The participants have not expressed any dissatisfaction or noted any faults in the application. Future evaluations should include more participants, both local and foreign to provide for a more strict statistical analysis of the results.

7 Conclusions

In this paper, we presented a novel methodology for teaching computer graphics, consisting of including basic artistic knowledge such as color theory and graphics design basics and developing specific skills in 3D modeling and AR applications development. The student surveys and marks, as well as the results of the BH Heritage AR application's initial user evaluation, show good results of this methodology. Out of 83 students attending the course, in the end, we had sixteen 10s, thirty-eight 9s, twenty-five 8s, four 7s, and no 6s or fails (passing marks are from 6-10). Students appreciated very much that their lab projects did not only serve for passing the course, but they remained as useful parts of a digital cultural heritage application that informs about BH cultural heritage and attracts visitors to cultural monuments in Bosnia and Herzegovina.

This is one of the very few courses in our Computer Science Department that encourages and develops the creativity of students, instead of teaching them dry algorithms and marking them according to a standard computer science pattern. This way of teaching CG encouraged many students to choose CG elective courses at the Masters level and expand their knowledge with computer animation, game development, and Virtual Reality.

In the future, we will expand the topic of the lab projects to other AR technology applications in education. For example, our students can create AR applications for learning biology, physics, mathematics, and geography that can be used in elementary and high schools to make the learning process more interesting.

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