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Quiz Cube: an AR mobile learning application

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Abstract—The current paper presents the Quiz Cube application and its evaluation. The Quiz Cube application is an AR mobile learning application for students and teachers to easily make and use AR UI system using fiducial marker cubes. AR as a platform is just now reaching its full potential. Since smartphones and mobile devices are now at a sufficiently large user base, it is worth looking at the potential for an extremely small form factor delivery system that is flexible, easily modified, and used by educators and students. An easily modifiable AR learning experience will present an AR Mobile platform development, interactive museums, and the chosen subject in a new style. This method can be shown to improve not only knowledge of the chosen subject through investigation, but a better understanding of development potentials for the mobile devices now ubiquitous to students. The Quiz Cube application was evaluated in three different ways and the results are presented here.

Keywords—mobile learning; Augmented Reality (AR); User Interface (UI); Quick Response Code (QR)

I. INTRODUCTION

Augmented reality (AR) is a way of enhancing reality by adding computer generated input to a view of the real world. AR can be used with many different types of devices such as the tablets that schools have available. Currently AR and QR codes are used frequently in museums and galleries where students have experienced interactive learning and even some basic development for mobile devices [2, 3]. We propose a new style of flipped augmented learning where students will investigate the museum or location to be augmented, then do the augmentation themselves by means of a structured development system that is web based with minimal overheads and technical constraints. This way they will think critically about the subject in order to develop questions, develop and publish an interactive tour on mobile devices using QR, AR and web technology, and take the tour and answer other students' questions on a tour they jointly authored.

There has been some basic work done in enabling student users to develop their own museum Augmented Reality applications. One example of this is in the "Talking Objects" project by the British Museum [3], which used Junaio to enable students to attach digital content to AR codes. However, like most AR authoring platforms, this is no longer freely available. The intention in this paper is to map out development of a system free of commercial and platform constraints so that educators can train students in development of Augmented Reality learning applications and experience flipped learning.

The story of Augmented Reality is one of academic research and freely shared open source software emerging during the late 20th and early 21st century [1]. The first Augmented Reality

tracking toolkit, AR Toolkit, made it straightforward to get a system working with a webcam, standard PC, and display screen. While intriguing, it seemed to be a problem in search of a solution. Variations of the software developed slowly with a certain amount of academic and hobbyist support, but little commercial traction.

At the same time, mobile computing devices such as smartphones and touch tablets developed enhanced capabilities beyond previous expectations, and began to be engineered into miniature mobile powerhouses. They acquired cameras on the back, then on the front as well. Video processing became accelerated by hardware and software innovations, and CPUs and GPUs enabled the real time processing necessary to overlay 3D rendered imagery on live video. Once that was available, the only factor to consider was the expansion of a suitable user base of such high end devices. At the current time, the data exchange connectivity between a huge installed user base of these smartphones has precipitated industry to greenlight large scale commercial products such as Pokémon Go that use AR on a massive scale.

Therefore, in the current technological and commercial climate, the wide array of developed AR Toolkits and frameworks are no longer starting or staying open source (apart from AR toolkit itself) [1], but are being snapped up by large companies for use on the smartphone, mobile and web platforms. A tipping point was at the beginning of this year reflecting the potential in mobile market as delivery system. A mature, largely homogenous hardware and software base now exists for large scale implementation of projects without large development, delivery or maintenance costs.

In just the last year, previously free software libraries such as those offered by QUALCOMM Vuforia, Metaio, and Junaio have migrated to a high commercial subscription model or been acquired by larger companies, effectively commercializing a great deal of work done by smaller free source developers. On the platforms these libraries use, HTML5, silverlight and other video and interactive rich media delivery formats for that has become the standard. Javascript offers interaction scripting, and new chips developed by AR and mobile companies may further standardize advanced AR capabilities for mobiles such as dedicated graphics processing and natural feature recognition.

Certainly large companies such as Google, Apple, Microsoft, Facebook and Nintendo are betting via various setups on AR being the next great mobile computing development. Microsoft has HoloLens, Google has MagicLeap, Apple has Metaio and their associated AR chipset and engine (in competition with Qualcomm and their Zeroth Chipset) and steals a march on others seeking to develop their own.

In this paper we present an educational application, Quiz Cube, which utilizes the AR technology together with a simple GUI as part of an innovative learning experience for young students. By setting a questionnaire framework that involves organizing visualized 3D objects together with relevant information using AR codes, the students are effectively studying the subject twice with a great deal of investigation. By interacting with the AR site questions, they will experience a new development of mobile learning, which is a novel experience even for the educators.

II. SYSTEM

Currently we are in the developing phase of a game prototype with underlying AR UI that can be used by educators in all mobile devices. The interface is developed with Alvar and Visual Studio, and reads AR codes (fiducials) from cameras in order to make overlays of images and perform actions. The current system (Fig.1) provides manipulation via various control markers. The right side will merely indicate functionality with an axis icon and placeholder blank graphic.



Fig. 1. Fiducials marker.

When moved to the left side, each fiducial will present a unique image from look up table and, if more than one fiducial is present, the left side of the screen will be divided on the horizontal axis to show the fiducials vertical order in the camera’s frame (Fig.2). Rearranging the fiducials will result in the images following and being rearranged.

With the addition of a fiducial cube, this can be made to act as a remote. Fiducial “articles” on the left have information revealed by the cube on the right. When there are multiple articles, moving the cube vertically to the field subdivision occupied by the article will bring up the related object information.

III. STRUCTURE

With all of the current advancements in mobile AR, the above system was adjusted to make a flexible and low maintenance AR and QR learning application for formal and informal learning. The Alvar code was repurposed to create a website based app. The awe.js allows a skeletal framework by which HTML5 websites can be managed with minimal technical intervention. This was done by placing user friendly GUI on top of this framework and limiting the scope of detection to QR codes for triggering questions on web pages. The advantage of this system is that, only one AR marker pattern is needed, to be

digitally distributed. The image and question management has been done on the server using a simple GUI. No further software, apps or graphics other than a QR scanner needs to be installed on the mobile devices. QR scanners are more generic than AR tracking apps, and a QR code generator [6] can be used to print out the required number, according to the number of questions.

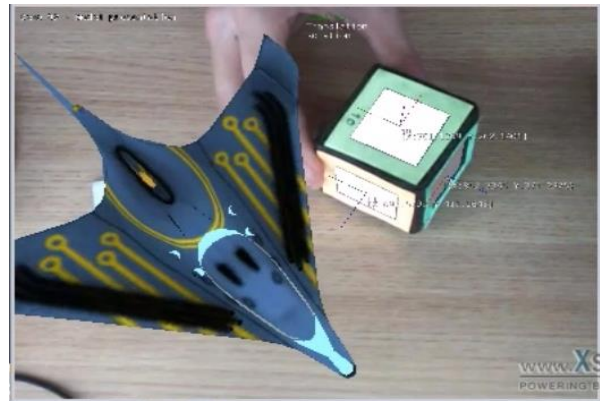


Fig. 2. Testing Demo using AR Toolkit to project object characteristics based on AR codes using a smartphone camera.

When the student views a QR code with a mobile device, they are sent to a hyperlink that contains a specific AR question running in html5. The Alvar code is integrated into HTML5 video app with Javascript [5]. AR tracking within HTML5 is more consistent over devices, obviates the need for a variety of specialist AR apps to be maintained for different mobile platforms, and offers the control and adjustment to the educators and students. The HTML5 platform can offer basic setup and login that the students can use as part of the learning process.

This small AR application can upload and present a different image for each AR marker via a lookup table in the web site server. These images are pertinent to the museum/gallery/location and the specific question referenced by the QR code. They can be stored in the software or the cloud, and can be updated as needed. This URL based setup is light, flexible, and takes advantage of broadband wireless connections to handle the delivery. It requires only one generic app type. A suitable QR code reader app can be suggested or even packaged if desired.

The HTML5 with video standard is widely accepted on mobile devices for access via a variety of modern web browsers. Nearly all smartphones come with cameras suitable for AR input.

IV. USE AND DIAGRAM

Students will be able to see all the museums in the application and choose (and eventually create and edit) the associated quizzes. A live video feed from the user’s camera device will detect the marker cube and display the corresponding 3D models. Then they can access the quizzes, answer the questions and get their score. The teachers can have access to all the scores and also manage all the students by adding, deleting or editing.

Once they have the question, they can flip the cube to see the images that are possible answers. They then select the correct one by lining up the cube marker with correct associated image

displayed and pressing the answer button. Their scores are recorded by the website, as well as timings and unique IDs. This information can then be available to teachers and parents via a separate secure URL. In this way, the student who uses the explorative nature of the AR app can be compared to those who learn by other methods to easily determine any benefits.

The context diagram (Fig. 3) shows the system and the entities that interact with it. The system is represented by the circle; the entities that interact with the system are represented by the rectangles. The arrows pointing to the system shows what the entity is doing to interact with the system and the arrows pointing to the entity show what the system is returning as a result. The students will have to log in to the application and select a quiz and point with their mobile camera at the fiducial marker. The teachers will also have to login but they will also have the ability to manage the students by adding, deleting and edit students details and also can see all the students' scores.

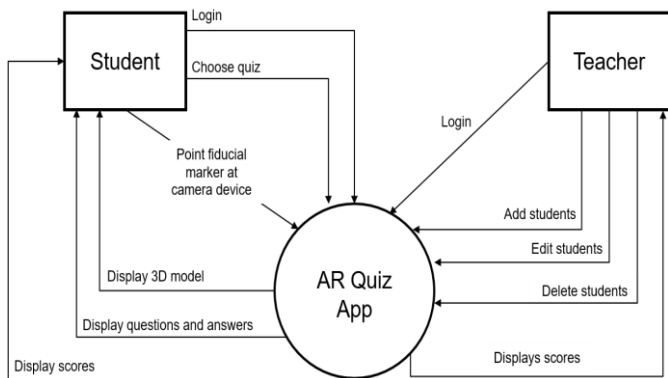


Fig. 3. Context diagram.

V. APPLICATION WIREFRAME

The wireframes of the main application pages can be seen in Figure 4 and Figure 5, followed by a brief description. The museum quizzes page will display the museums with a description, a related image and a button. When the button is clicked, it will direct the user to view all of their quizzes. Each student page, except the home, question and score page have a menu button positioned at the top left corner of the screen, when clicked, it will push a menu bar to the right of the screen. All the options available on the home page are also available in the menu bar to allow the user to navigate through the application without having to return to main menu each time.

The quiz menu page displays the name of the museum chosen from the previous page with the word 'quizzes' following. The quizzes are displayed in a list, displaying the name, average score and the number of attempts remaining. The user can click the start quiz button to start the quiz of their choice.

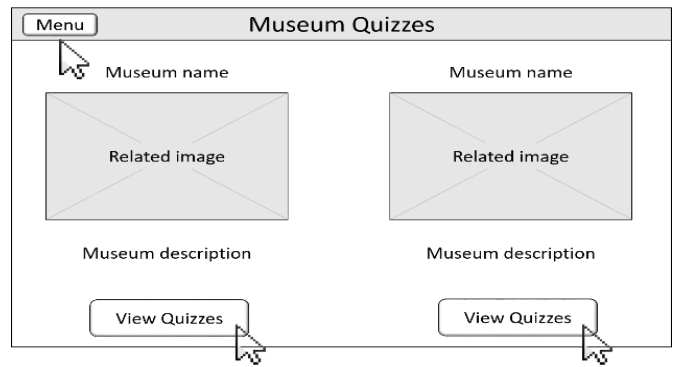


Fig. 4. Museums page.

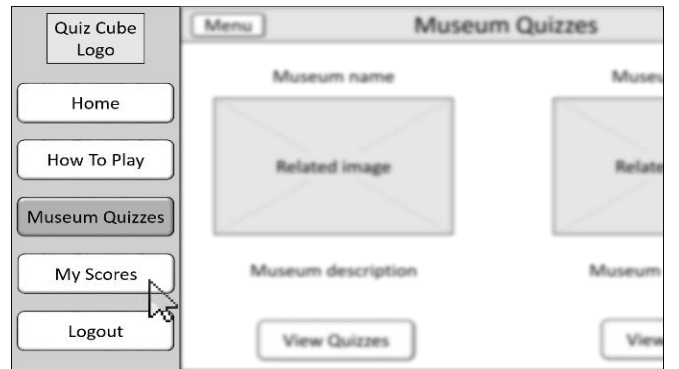


Fig. 5. Side bar menu.

The quiz question page displays the quiz name in the header. At the top of the page the question number will be displayed to inform the user how much progress they have made. Under the question number is the question text. Under the question text is a box displaying the live video feed from the user's camera device to detect the marker cube and display the corresponding 3D models. Below the video feed are the four answer options which the user can choose from. At the top left corner of the screen will be a hint button, when clicked, it will display a hint on the page. At the top right corner of the screen will be a quit button, when clicked, it will end the quiz and take the user to the results page.

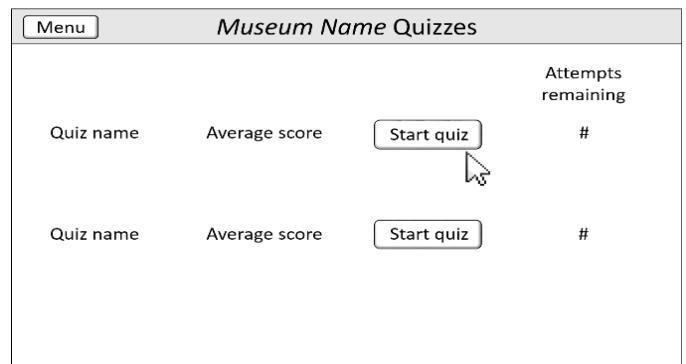


Fig. 6. Museum quizzes page.

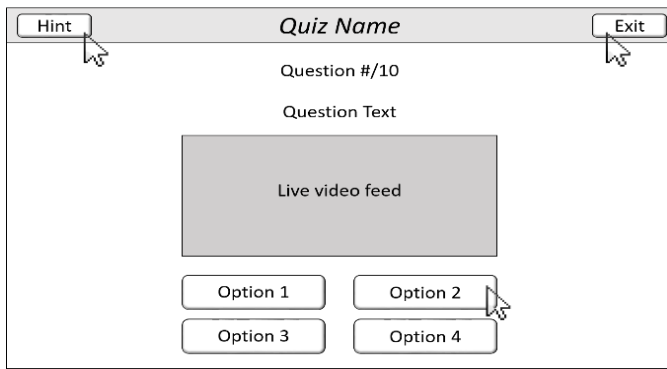


Fig. 7. Quiz page.

VI. EVALUATION

For the evaluation of the Quiz Cube application 3 types of testing were used, black-box, white-box and user experience testing using a standard SUS questionnaire [8].

A. Black-Box Testing

Black-box testing is method of software testing which focuses on analysing the software functionality without knowing the internal structure or implementation. This is a great method to verify the fulfillment of the functional requirements which were initially planned at the design and requirement stage.

Based on the objectives of the application 18 functional requirements were developed. The requirements were the following:

- [FR1] Each student will have an individual login (Essential)
- [FR2] All teachers will use the same login (Essential)
- [FR3] The application will allow access to users with correct login details (Essential)
- [FR4] The logged in user will be able to log out (Essential)
- [FR5] The teacher will manage all the student accounts (Essential)
- [FR6] The student will be able to view their score from previous quizzes (Essential)
- [FR7] The teacher will be able to view all the students' scores (Essential)
- [FR8] The teacher should be able to filter the students' scores (Desirable)
- [FR9] The student will be able to view all quizzes (Essential)
- [FR10] The student will be able to take a quiz (Essential).
- [FR11] Each question in a quiz will have 4 answer options (Essential)
- [FR12] The student will be able to choose an answer (Essential)
- [FR13] The student should be able to take a quiz 3 times (Desirable)
- [FR14] The student should be able to see the scores of all the attempts of a quiz (Desirable)
- [FR15] The application will calculate the student's score (Essential)
- [FR16] The student will be able to end a quiz at any time (Essential)
- [FR17] The application will display a 3D model when a marker is pointed at the camera device (Essential)

[FR18] The application will have quizzes for the main museums in the UK (Luxury).

The black-box testing was carried out by five Computer Science students at the University of Westminster. The result showed that eighteen out of twenty requirements were accomplished. The two functional requirements that were not functioning as intended were FR8 and FR18. The functional requirement FR8 had been labeled as desirable and FR11 as luxury, and there was no negative effect on the overall final application.

B. White-Box Testing

White-box testing is a method of software testing which focuses on the internal structures and implementation which is the opposite of black-box testing. "One of the basic goals of white-box testing is to verify a working flow for an application. It involves testing a series of predefined inputs against expected or desired outputs so that when a specific input does not result in the expected output, you have encountered a bug" [7].

The white-box testing was carried out by the same five Computer Science students who carried out the black-box testing. The testing took place at the University of Westminster, UK. The white-box testing included 21 cases which were derived from the functional requirements. The testing purpose was described for each case and the expected outcome was defined. Then, the actual outcome was recorded and the corrective action, if needed, was described. The white-box cases included verification of logging in, logging out, verifying the scores, addition and subtraction of points, total score, loading results, saving scores, displaying scores, displaying attempts to solve the quiz, teachers adding students etc.

The results were positive, meaning that all the inputs produced the desired outputs and no corrective actions needed. The internal structure and implementation of the application worked as expected for every test performed. These results can be explained from the implementation strategy. Every functionality was tested until was fully functional and then and only then new functionalities were introduced. The white-box testing confirmed that the internal structure and implementation of the application was sound and did not produce any unexpected errors.

C. User Experience Testing

User experience testing is about gathering the users' view of what they think, as they interact with the application. UX testing is the best way to discover what works well, what doesn't work, and why. 10 students of The University of Westminster took part into the evaluation and they had to use the Quiz Cube application and answer a questionnaire. All students had to fill in a participation information sheet and consent form before testing. The information sheet is to inform the students of the research study, for the usability of the Quiz Cube application they wish to participate in. The consent form is to confirm their participation and their acknowledgement of the use of the data they provide.

The testing is made up of two parts, rating of the System/UI Usability [8] and System/UI Learning [9]. The user's responses were recorded using a questionnaire consisting of 16 questions, 10 referring to the system usability and 6 to the system learning.

The results (Table 1) showed a strong correlation with the responses received from the System/UI usability questions. None of the responses for the questions were more than one rating apart and were always on the positive end of the scale. This does not necessarily mean the application/UI usability is perfect however it shows that there are no identifiable aspects of the application that requires attention. The participants all shared similar opinions on the system/UI usability. The table below (Table I) shows the average scores of the users.

TABLE I. AVERAGE RESULTS OF SYSTEM/UI USABILITY QUESTIONS

Question	Average
1	4.3
2	1.2
3	4.8
4	1
5	4.7
6	1.7
7	5
8	1.5
9	4.8
10	1.1

Regarding the learning experience the results (Table II) were similar to the usability ones. There was a strong correlation with the responses received from the system/UI learning questions. However, question 4 had an average rating as opposed to a positive one. This question addressed the helpfulness of messages displayed on the screen. The Quiz Cube application often displays alerts about the applications state and during quizzes when the users choses an incorrect answer. The result showed that the use of alerts was not helpful and it was dimed unnecessary as it takes the user away from the experience. All of the other responses (see Table 2) were very positive showing that the learning experience was very enjoyable.

TABLE II. AVERAGE RESULTS OF SYSTEM/UI LEARNING QUESTIONS.

Question	Average
1	4.7
2	5
3	4.7
4	3.9
5	4.1
6	4.4

VII. CONCLUSION

The advantage of this system could be the ability for educators to tailor and update the system for their own scenario. The educator and students could use the building of the interactive system to map out knowledge of the subject matter by setting questions for specific subjects and make the entire learning procedure more interactive

The standard cube could be distributed as a pdf for printing and assembly by students, therefore keeping distribution digital, flexible and cost effective. Since AR museum apps are reasonably common, the advantage of a web platform should also be investigated for ease of use. Lastly, the digital development learning is an emerging aspect to the typical museum AR application. The learning outcomes of this should be defined and measured against digital development conducted solely in the classroom.

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