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ORIGINAL RESEARCH

Augmented Reality-Enabled Education for Middle Schools

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Abstract
Augmented reality acts as an add-on to teachers while teaching students, and this helps the teachers and students to have an interactive session. Augmented reality's usage in education is cited as one of the major changes in the educational sector. Thus, the work carried out makes a positive impact in the educational industry. Augmented reality provides features like image recogntion, motion tracking, facial recognition, plane detection, etc., to provide interactive sessions. Simultaneous localization and mapping and concurrent odometry and mapping have proved to be efficient algorithms for augmented reality on mobile devices. The work carried out allows students to view interactive newspapers while reading a specific article. It also allows them to view a dynamic three-dimensional model of the solar system on their smartphone using augmented reality.

Keywords Augmented reality · Education · Mobile application

Introduction

Augmented reality is an experience, most commonly over the camera of a smart mobile phone, where computer vision is used to place, or "augment" virtual objects and scenes on top of the real world. The augmentation is said to be complete when the user-placed objects and scenes interact with the objects and the environment in the real world.

The idea of augmented reality was first introduced to the world in the year 1901, when science fiction writer L. Frank Baum discussed about virtually modifying the real world using something called as "character markers". But the term "augmented reality" was not used formally until the year 1990, and it was attributed to Thomas P. Caudell, who was a Boeing researcher.

The work carried out focuses on providing an additional add-on to the teachers so that they can explain interesting topics to the student in an interactive session. This project does not look to replace the chalk-and-talk method, but instead of replacing, it is meant to aid the pre-existing chalk-and-talk method. The technology used for this project is a new and upcoming technology, called augmented reality, and it carries out its functions using computer vision and is hence able to make use of image recognition, motion tracking, and plane detection.

All these technologies, if implemented for the education of young students, help them to understand complicated and interesting topics in an interactive manner. This increases their curiosity not only for the topics at hand, but also for the technology used to deliver the experience. This project is aimed at providing additional help to the teachers. Augmented reality will soon be used in almost all verticals of manufacturing, development, human resources and supply chain management.

The problem observed was that the current teaching methodology used in schools is not up to date with the technological advancements. Concepts that are interesting in middle school are taught in long lectures where students eventually lose focus. This was one of the major problems observed. Also, the limited use of augmented reality in the educational sector was another problem observed.

Under this, the reason for choosing the particular problem or title for the project shall be explained along with the thought process that was involved in doing so.

This article is part of the topical collection "Advances in Computational Approaches for Artificial Intelligence, Image Processing, IoT and Cloud Applications" guest edited by Bhanu Prakash K N and M. Shivakumar.

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The work carried out is based on the assumption that majority of the students in middle schools have a smartphone with them, preferably running on the android operating system. This can become a limitation if the assumption fails.

Another limitation of the work carried out is that the smartphones must be ARCore enabled. All the android phones released in the past 3 years are all ARCore enabled.

Methodology

Background

The focus was on the method of learning which was being provided to the students. In a world where Augmented reality and Virtual reality are growing at an extremely rapid pace, [1, 2] we needed to implement something called as Educational Entrepreneurship. This entails bringing subjects to students using novel methods, which aim at making teaching and learning a fun experience. Students, in the modern classroom, still study in the traditional methods. We aim at changing that with including technology into the field of education and providing a better and more interactive way of learning [3, 4].

Design

The first phase, which was the requirements phase, was the recognition of the problem statement. The observation that education in middle schools is still being carried out by old, traditional methods was done and that was viewed to be the main problem, statement.

The second phase was the analysis phase. In this phase, the various technologies, which could possibly be used for the education in middle schools, were observed, such as virtual reality, mixed reality, and augmented reality. The most affordable technology with the widest reach was augmented reality, since it requires no extra head-mounted display, or any expensive equipment with senders and receivers. Augmented reality is the view which is created when virtual objects are placed or "augmented" on top of the real-world view of a camera or a head-mounted display. Augmented reality, to make the experience more realistic, uses features such as plane detection and image recognition, and depends on algorithms such as simultaneous localization and mapping, also called as SLAM to detect the environment around them and to calculate the position and orientation of the camera or the device in the real world.

The third phase was the design phase. The various possibilities of the software were observed, and the programming languages were decided, based on the knowledge of the authors. Eventually, the game engine unity was decided to be the crux of the project, along with ARCore by Google enabling the augmented reality experience. The programming language was chosen to be C\#. For the user authentication, firebase, also by Google, was decided to be the best option.

The fourth phase was the implementation phase. In this phase, the entire coding, animation, and the interconnection were carried out. All of the code was written in C# in Visual Studio. Firebase authentication objects were created so as to send and receive data to and from the firebase application console. The data consisted of the email address and the password with which the user logged in the application. The user could either log in, if they were an existing user, or they could sign in, if they were a new user. All the various possibilities were also added for students, such as the interactive newspaper. All the features of plane detection and image recognition was also carried out in this phase.

The fifth phase was the deployment phase. The application was deployed on the Play Store, which is the application store for android. This was done so that users can download and experience the application first hand.

The sixth phase was the testing phase. There were a few bugs found in the phone Motorola G4 plus, but they were solved and the application was updated on the play store (Fig. 1).

The experience was created using the Unity Game engine version 2018.2 [5]. Unity is an excellent software to create

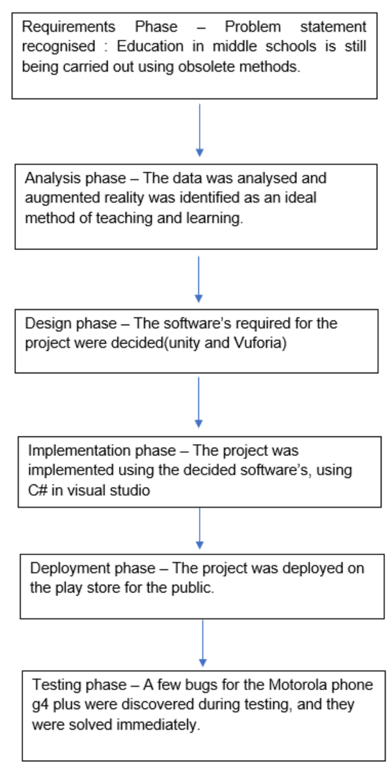

Fig. 1 Project lifecycle

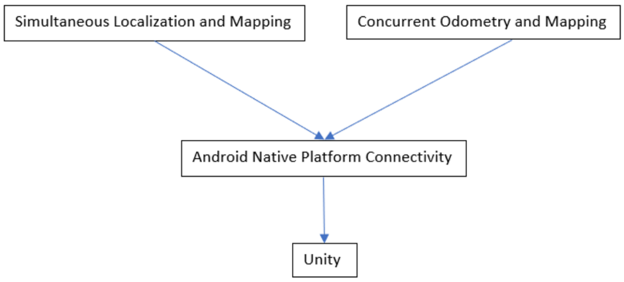

Fig. 2 Architecture flow of augmented reality

models, interactive designs, movies, and obviously, games. Unity, along with handful of other providers, gives the functionality to develop for augmented reality, virtual reality, and mixed reality as well. The functionality of ARCore, and firebase was used simultaneously to complete the experience (Fig. 2).

Unity provides for multiple options and SDK's which can be used for augmented reality development. Vuforia and ARCore are the two most popular SDKs. ARCore was selected instead of Vuforia for this paper since ARCore [6] provides much better plane detection, pose tracking, motion tracking, and image recognition than Vuforia. The only downside of ARCore is that it runs of certain mobile phones, but all phones released in the past 3 years have ARCore enabled in them.

ARCore is an SDK (Software Development Kit) provided by Google which allows for smooth computer vision, plane detection and motion tracking in certain Android mobile phones. ARCore allows for better augmented reality experiences since it can detect planes(in proper lighting conditions) in 2 s approximately. ARCore was earlier called "Project Tango" by Google. Project Tango provided specific hardware in certain mobile phones so as to allow for better computer vision and plane detection, and it was later converted commercially to ARCore. ARCore does not require specific hardware, since most of the latest processors are capable enough to provide the computing power required by ARCore. Because of Unity's popularity, ARCore development comes built in with Unity.

Firebase was also used in this project. Firebase is an application development platform, also provided by Google. Firebase provides a real-time database, machine learning kit, authentication services, and many more services, most of which can be used free of cost by developers. The service used in this current implementation of the project is Authentication services. Firebase application programming interface allows for manipulation of the data which is being sent and received from the user and the database.

The implementation consists of multiple modules, such as an interactive model of the solar system, an interactive three-dimensional model of the earth, interactive newspaper and an interactive three dimensional model of the leaf.

The coding for the interaction, the augmented reality view and the controlling the three-dimensional models was done in the C#(C Sharp), using the Visual Studio IDE and MonoDevelop.

Unity accesses the raw touch inputs which a user provides to the smartphone screen and allows the developer to carry out certain functionalities.

The ARCore SDK scriptable components were accessed from Visual Studio. The ARCore SDK acted as an intermediate between the software and the hardware of the mobile device. This functionality was accessed by Unity, which was then used to create the mobile application (Fig. 3).

The ARCore Software Development Kit (SDK) integrates two of the main tools which are used to create a successful augmented reality application: simultaneous localization and mapping (SLAM) [7], and platform enablers. SLAM is used to find the location of the user in the real world in three-dimensional space and convert it into coordinates which are accessible by ARCore SDK. The platform enablers allow Unity to access the camera and Inertial movement unit (which includes the gyroscope and the accelerometer) values to carry out SLAM. ARCore also uses concurrent odometry and mapping (COM) method to find the pose of the user and recognize their surroundings and their environment. The longer COM is active, the better the recognition of the surroundings and the environment.

The work that has been done implements the latest current technology, that is, augmented reality. The implementation of this technology allows for interesting discussions between the users and the developers. The creation of the various experiences, such as the interactive newspaper and the model of the solar system are examples of ideas that seem very futuristic, but are currently possible. This allows for creativity in the students and makes them interested not only in the modules provided in the application, but also in the technology that is driving those modules.

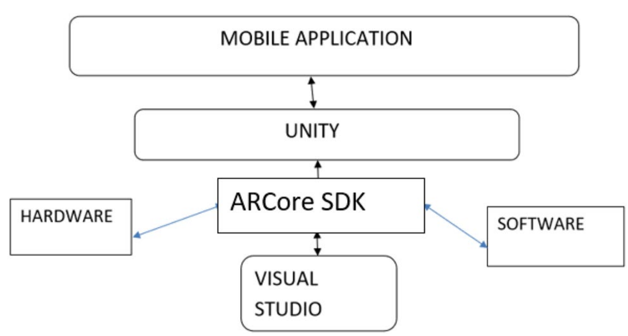

Fig. 3 Architecture diagram of the project along with software components

The security features of the entire framework have been taken care of by Google firebase authentication. This method of authentication will ask the user for their email account and password before accessing the application, to sign in. The user will also have to provide their phone number, on which a One Time Password (OTP) will be sent, which will also be required to authenticate the account of the user. All these features provide ample security for the framework. The data provided by the user is secured through Secure Socket Layers, and hence, there is no danger of losing data to third parties without consent of the user.

Experimental Results

The solar system is an interactive, 3D model of the solar system. The various planets are seen to be revolving around the sun. If the user taps on any of the planets or the sun, then a new scene opens up which describes the celestial object they had tapped on. The earth is included with its moon. Currently, the earth is the only planet with a satellite depicted in the model.

The projectile motion is an example of projectile motion which is displayed by placing the objects on a plane which is detected by the camera using computer vision. The object is thrown in a general direction at a particular angle, and the position where it will land is highlighted in red.

The interactive newspaper is an implementation of image recognition in augmented reality. Once the interactive newspaper button is clicked, the camera is looking for images it can recognize on newspapers. If the image is recognized and is matched with any one of the images in the database, then a video is played right on top of the image with the size of the video player corresponding to the size of the image. The video player stops playing only when the image is currently not being tracked, and when the video runs its length.

The 3D model of the earth is an interactive model of the earth, which appears once an image of the earth is recognized by the camera. The moment the image is recognized, and the 3D model of the earth appears on the camera view.

The following suggests the possible outcome of the project. The firebase authentication integration allows for the user to either log in or sign up using an existing email address and a password of their choice. If they are a first time user, they have to sign up with their credentials. If they are an existing user and want to access the application, they have to log in using their provided email address and password.

Once they have logged in, they view a page which asks them whether they are a teacher or a student. If the student button is clicked, the user is moved to a new page which displays all the current possibilities which can be accessed within the application. The current possibilities are an interactive model of the Solar System, an interactive newspaper, an interactive model of a leaf, and its anatomy and an interactive model of the earth. Future enhancements entail actions such as viewing projectile motion on a surface detected by the camera.

The augmented reality implementation depends on various factors such as plane detection and image recognition.

The application was prototyped and tested in a Motorola G4 Plus phone. The augmented reality experience for the solar system was lagging due to low computational power, and hence optimization was carried out, where the high-quality textures of the planets and the sun were reduced to low to medium quality, which solved the issue of overheating and lag. All the testing of the authentication was also carried out on the same mobile phone (Motorola G4 plus). The code was tested using Visual Studio NuGet plug-in for testing C sharp modules.

The augmented reality implementation depends on the values of the accelerometer, the gyroscope and the pose tracking carried out by ARCore using Concurrent Odometry and Mapping (COM). The union of all these features allows for very stable 6-DOF(Degrees of Freedom) tracking. Once a plane surface is detected, we can place an object anywhere on the surface. The object follows motion laws, and decreases in size when the camera is taken further away and increases in size when the camera is taken closer to the object.

Table 1 [8] is an example of possible values for yaw, pitch, roll, elevation, zoom, high elevation and the basic movement values which are acquired from the gyroscope.

The following are screenshots of the application:

Figure 4 shows the first screen which appears when the application is started. The application gives the user two

Table 1 Possible values of gyroscope reading for yaw, pitch, roll, elevation, zoom, and high rotation

Sequence	Average translation	Average yaw	Average pitch	Average roll
Basic	0.183048	3.56152	2.13641	2.49864
High rotation	0.338489	6.29521	10.7688	4.14102
Zoom	0.28821	1.32546	6.15959	2.60276
Elevation	0.550592	1.04715	3.07357	1.44375
Yaw	0.330875	16.9989	2.28565	2.01913
Pitch	0.134763	0.416974	12.2647	0.607089
Roll	0.366743	1.19815	1.3348	12.2657

Fig. 4 Log-in/sign-up screen

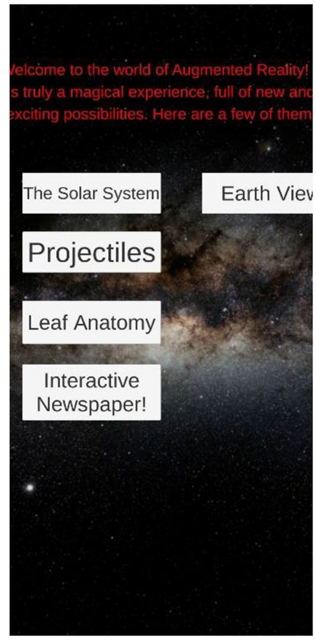

Fig. 5 The options scene for the student

choices: Whether to sign up if they are a new user, or to log in, if they are an existing user.

The authentication module makes use of the firebase API. The firebase API allows for storing the users who have signed in or logged in and shows the timestamp of each of the sessions that they were active. For this service to be active, the mobile phone needs to be connected to the internet so as to send data and receive data to and from the firebase console.

From the console, the owner of the application can delete or disable the account which is connected to the application if any suspicious activity is found. The password is encrypted while being sent to the firebase console, and hence security issues are drastically low.

Figure 5 shows the list of possibilities which are available to the student as part of the augmented reality experience. The list includes options like the interactive model of the Solar System, the interactive model of the earth, the interactive model of the leaf and its anatomy, and the interactive newspaper.

This project assumes that the student already has a smartphone which was released sometime in the past four years and runs on the Android operating system. Apart from the above-mentioned requirement, the only other requirement is the need of an internet connection, which has become cheap in recent times. The application is available for free on the Play Store, and the requirement of an email account is also free. The estimated cost of the work carried out is better than the existing system [9, 10]. Hence, the initial investment is minimal, compared to other augmented reality solutions, which provide fewer benefits at a high price.

Figure 6a, b show the example of the interactive newspaper. Figure 5 shows the image which will trigger the video to

Fig. 6 **a** Camera view of the image. **b** Video playing on top of image

start playing. The image is recognized and the video player canvas is placed on top of the recognized image, by using

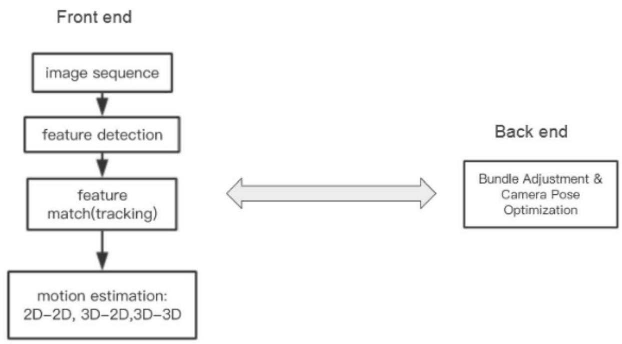

Fig. 7 Flowchart of the functioning of Visual SLAM

its *X*, *Y*, and *Z* vector coordinates. Figure 6 shows the video player canvas which appears in front of the image. The canvas disappears when the image is no longer recognized, or the video has run its course and finishes playing.

Algorithm Used

To implement marker-less augmented reality, a variation of the SLAM [11] algorithm was used, which provided a localized map of the surrounding environment.

The following is an algorithm which is used to map the local environment around the user:

Algorithm:

MapTargetCreation():
//create keyframes for local map
If (keyframe_dist<20 and nnratio>0.65), then do the following:
Add keyframes to localised map.

//removal of redundant keyframes
If keyframe==map_kf(1,2,3), then
Remove keyframe.

The above algorithm defines a method of selecting keyframes and creating a localized map using those selected keyframes. Once this is done, then the virtual objects can be placed on the map as and when needed.

The algorithm has been selected since SLAM has been proven in robotics to provide easy localization of the surrounding environment of the camera. Also, this variation of SLAM is implemented since it not only localizes and maps the surroundings, it also removes loops in the maps which may lead to endless cycles, and gaps in the mapping. The removal of redundant keyframes allows for new keyframes to be added continuously, and hence this method will not spend time mapping an area which has already been mapped in an earlier iteration of the algorithm.

Simultaneous localization and mapping (SLAM) is used to localize the location of the device without the involvement of GPS. This makes SLAM an integral method in augmented reality software development kits, like Vuforia. SLAM method finds the position and orientation of the device with respect to the surrounding. This is called the pose of the device.

The loop closure is also carried out in this algorithm, since without loop closure, the accurate pose of the device would not be accessible. Loop closure is extremely necessary, since the device can be globally mapped in the wrong location where it has already been before. The methods of loop correction are optimize the current graph and loop fusion. These methods close all loops in the graph, so as to avoid complete incorrectness of the final camera pose. The main method to avoid loops is sending appropriate queries to the database of camera pose and motion estimation.

Visual SLAM [12] is used to find the pose of the device (the camera) using 3D imagery of the surroundings, when both the environment and the location of the camera is not known.

The image sequence is the input in the V-SLAM algorithm. The next step is to access the feature points of the input. After the feature points have been accessed, the tracking methods must be applied for the device. Then, the motion of the camera\device is estimated using 3D–3D, 3D–2D, or 2D–3D method.

All this data is sent to the back end, where the pose of the camera is determined using these inputs. The above-mentioned algorithm implements the local mapping aspect of the Visual SLAM methodology (Fig. 7).

Conclusion

The work carried out was created with the aim of providing the students with interesting and interactive modules created with the latest technology. Augmented reality has multiple use cases, and the most promising one is its application in the educational sector. The ability of developers to be able to develop applications for augmented reality using a popular game engine such as Unity and being supported by ARCore provided by Google makes it even better. The application has the scope and scalability of being able to be used by hundreds and thousands of students, free of cost. New modules, supporting education for higher grades can also be implemented. The work carried out can be extended to be fully integrated in the educational curriculum of middle schools. The application can have many more modules present for the students, such as a virtual assistant, created using the Watson Software Development Kit provided as an open-source SDK by IBM. Another possible enhancement point is carrying out instantaneous recognition of images currently in the camera stream and providing details about the object, although that feature may have uses outside the education sector also.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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