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Interactive Science Learning using Handheld-AR

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Abstract: Current education system is rapidly growing in complexity, uncertainty, size and interdisciplinary characteristics. Number of students complains that there exists a lack of engagement and interaction with the learning environment. A major issue is that most of the teachers rely on traditional aids for teaching and it includes very little visual information. According to a number of recent surveys, these traditional techniques are considered as less interactive. Apart from the class room, the engagement of student with the study material is almost nonexistent. At the same time, the influence of smart phones in every aspect of daily life has changed students' view of learning and their expectation about the Study materials' presentation. Smart phones have all components that are required to implement an Augmented Reality (AR) application where the virtual 3D Objects are superimposed on the real world. The paper proposes an innovative mobile based application for learning that uses AR, thereby creating an interactive interface for students. The AR based application increases their interest of learning new things by exploring the 3D Objects. This app is also designed to support the touch based interaction with the 3D Objects. This new learning environment helps the students to develop an in-depth understanding of the subject and other operational issues.

INTRODUCTION

AR is a technology where physical world merges with virtual world, creating an improvised environment for its users. AR is a great tool to visualize complex data but to be used in applications that benefit from a merger between the digital and physical worl[1]. The goal is to evaluate the use of AR in learning processes for School students. AR can be applied to education, for the reasons listed below:

- AR supports seamless interaction between virtual and real environments
- AR allows using a touchable interface for object manipulation
- AR provides the ability to transit between virtual environment and reality

Augmented reality application can also be used as a learning tool in which students are able to build conceptual models on which it includes both new content

Fig. 1: Mapping of different augmented reality systems

and consistent with what they already understand. Such that models can be improvised by integrating information with 3Dimensional representations. It includes diagrams, 2D images, audio and text annotations. AR can improvise the learning experience using traditional aids:

- The ability to understand the ideas and concepts through interaction
- Making mistakes during the AR learning process will literally have no real consequence whereas in traditional learning, failure to follow precautions or rules would lead to serious health and safety related problems
- AR supports discovery-based learning which is a learning method in which students can control their own learning environment, acquire knowledge and use that in experience scenarios[2]

AR in handheld devices: AR systems depend on technologies that recognize and track the physical world around us with the goal to visualize and render virtual objects in it. The architecture of AR systems differs and can be categorized depending on the scene capturing, user interaction, detection/tracking method and visualization (Fig. 1).

The scene capturing can be done using wearables (e.g., HMD, Google Glass) or handheld devices (e.g., tablets, smart phones). The detection and tracking methods includes the use of GPS, inertial tracking, compass (using accelerometers and gyroscopes), optical tracking (marker-based or marker-less) or magnetic tracking (using magnetometers). The visualization can be done using video see- through (video stream and opaque HMD), optical see-through (transparent HMD), monitor based, projector based technologies (projections onto real world objects). This proposed work focuses on Physical interaction with optical detection using handheld devices. The optical tracking and detection perceives the world through a camera, e.g., a smart phone camera and the detection can be made using marker-based or marker-less techniques.

Marker-based system architecture: The proposed work is done based on marker-based system which includes interaction with optical detection in handheld devices. The general approach of marker-based system is illustrated in Fig. 2.

Preprocessing: The images that are preprocessed are taken from the camera's stream. In order to process images an image binarization is made[3]. The binarization operation makes sure that every pixel is either 0 or 1 and is performed using a thresholding algorithm. It applies one threshold to the entire image, making a pixel white or black depending on given value. This method is highly dependent upon the intensity and lighting changes. Other

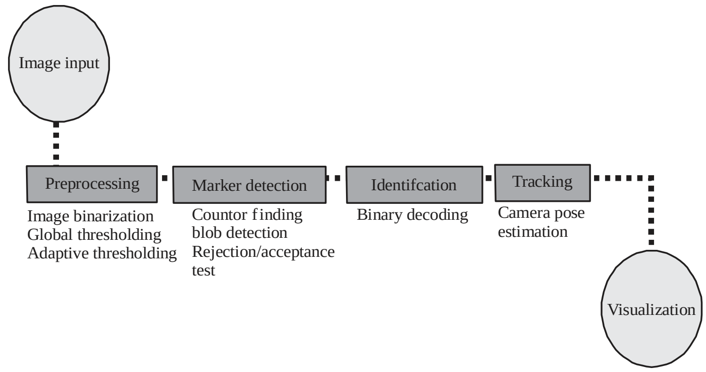

Fig. 2: The process of an AR marker-based system

method is Adaptive thresholding which uses different thresholds depending on patches of image, making it robust against different lighting conditions.

Marker detection: The detection method will depend on the design of the marker. Square markers are detected searching for contours and lines Suzuki[4] proposes one contour detection algorithm for square based markers on which the markers are four-sided quads with a black border. If the detected lines are contours, or if they belong to a quad, they are stored as marker candidates together with their corresponding corners. The detection can be done in different ways. If a candidate fulfills the requirements it is stored as a marker.

Identification: Once the marker detected, the code contained within it is extracted to check validity of the marker. The information encoded from the marker is an ID number which is used to connect the marker to certain meta-data. The square markers are divided into smaller squares. To be able to extract the code the perspective projection of the marker needs to be removed. Marker systems use Hamming distances for error correction.

Tracking: The tracking plays a main role to make the augmentation feel in a seamless way. Tracking meant to be the camera pose that is being calculated for each frame. The camera pose describes the relation between the marker and camera and used to position the virtual objects. It will return a transformation matrix which includes a rotation and translation.

Visualization: The final process is to position the virtual objects in the physical world. This is done using transformation given by the pose estimation.

Different types of ar SDK's-comparison: The potential of AR have resulted in, companies to start developing the complete AR solutions targeting developers. An independent AR application developing organization has listed the top AR SDKs for developing mobile AR applications[5]. The various specifications can be found at the AR World Expo's website[5].

Qualcomm Vuforia: Vuforia is a software platform offering solutions for AR developers. Vuforia supports both Android and iOS. The SDK is free to use and free to publish with. The SDK allows the tracking of 2D images, markers and text. Vuforia offers an extension to unity 3D, a tool used as a rendering engine to visualize the virtual objects.

Metaio SDK: Metaio SDK is a complete AR solution which is meant to handles both rendering and tracking. Metaio supports both Android and iOS. It requires licensing to be used without a watermark. Metaio detects 2D images, location and 3D objects using NTF, GPS and SLAM, respectively. The SDK further allows the use of 2D barcodes and QR-codes. One special feature Metaio has implemented and patented is to add a sense of gravity to the augmented objects. Metaio does not have the large developer community that Vuforia offers. Metaio could be integrated with unity 3D for the visualization and rendering of virtual objects.

Wikitude SDK: Wikitude support detection of location and 2D images[6]. The tracking uses GPS or NTF respectively. The system runs on iOS android and Blackberry but it requires licensing.

Layar SDK: Layar tracks 2D images and location using GPS or NTF, respectively. It runs on Android and iOS which requires licensing.

13th Lab Point Cloud: 13th Lab is a small Swedish company that is exploring SLAM to handle marker-less AR. The system runs on both iOS and Android, it require licensing. 13th Lab could also be integrated with Unity3D to render and visualize virtual objects.

Vuforia SDK and Unity 3D: By comparing the above AR marker-based systems and SDKs, a system for the implementation would be Vuforia SDK and unity 3D. Since it satisfies the following requirements:

- Track and detect markers in real time on a mobile device
- Allow for occlusion management during tracking
- Extended tracking
- Allows interaction
- Can have small, unobtrusive markers

Vuforia's SDK includes different recognizable real world objects, called trackables. The tracking and detection algorithm uses Natural Feature Tracking and Detection which allows the system to match elements in the image with targets in a predefined set. Different elements have different ease of being recognized. The current trackables that Vuforia handles are cylinder targets, frame markers, image targets, multi-targets and words. When the marker is detected, Vuforia returns a trackable result which includes the references to the matching target and a status for it and the position matrix. The position matrix represents orientation and the current location of the marker with respect to the camera's coordinate system. The content rendering can be done using unity 3D. Vuforia provides an extension package to Unity that allows developers to use vision tracking and detection within the unity IDE. Unity is originally a cross-platform 3D game engine[7]. It allows for the creation of simple geometrical objects such as cubes, spheres or rectangles but it is essentially a tool to enable the behavior of 3D models imported from 3D programs. The behavior of the models is specified using scripts written in either C#, JavaScript or Boo.

MATERIALS AND METHODS

Problem with current teaching/learning methodology Traditional teaching methods are used in most of the educational institutions in India on which teachers or instructors explain the concept to the students with the help of blackboard and chalks. Every important point regarding the subject is written in it and students make note of it. Even though some of the Instructors prefer graphical or contextual information like animations, PowerPoint presentation, 3d objects etc., for their presentation, they are available in classroom alone. Other than classroom, Students lack interest in learning due to the impact of Smart phones and lack of engagement with the self study material. Modern teaching methods have various advantages over traditional teaching methods. These points can also be viewed as drawbacks of Traditional teaching methods:

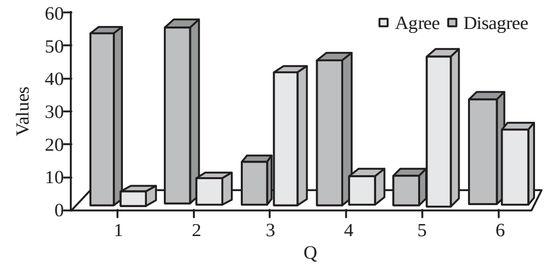

Fig. 3: Survey on traditional teaching methods

- Modern teaching method creates more interest with the help of interesting 3d models and animations
- Recent Survey has shown that use of visual media for learning helps the students to understand the subject better
- Modern teaching methods are less time consuming

Survey on school students: To get the Students opinion or view about their learning environment, an initial level survey was conducted. The main objective of the survey was to compare the traditional teaching methods and AR-based learning approach. Figure 3 shows the results of the survey Conducted. Survey includes two sections. Section A describes about the Traditional Teaching -learning approach and Section B includes AR-based Learning which was obtained (Description of Section B was in VI Section). Section A includes the following questions.

- Q1: I learn better while experiencing a collaborative setting where I can play a role in the learning process?
- Q2: Do you understand the concept in detail in traditional teaching methodologies?
- Q3: Is the traditional teaching methodologies feels more time consuming?
- Q4: I learn better when instructor uses 3 dimensional representation or visualization technique to teach?
- Q5: Apart from classroom, I have interest in using the Study material?
- Q6: I get bored when, I use traditional learning materials
- Q7: The use of the traditional learning materials improved my interest in this course

From the above results (Fig. 3), it clearly shows that the concept or information delivered was less understandable in Traditional Teaching methods. Precisely, the Students opinion was, the traditional teaching method was more time consuming and 90% of them learn better when instructor uses 3D visualization or representation to teach and they feel that the practical app is more interactive. Treagust and Mills discussed

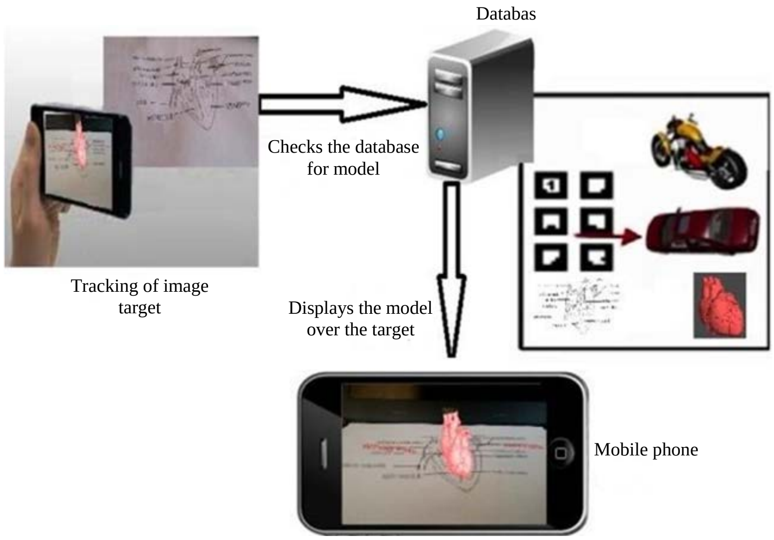

Fig. 4: Working of AR

that most of the students were graduating with descent knowledge of fundamental science but they don't have exposure to apply that knowledge in practice. One among the fastest emerging technologies in education is visualization. However, none of the Traditional teaching techniques are capable of effectively conveying concept on every aspect of a subject.

Interactive learning AR APP: The major issue with current teaching/learning environment is lack of engagement of students. By presenting the object in graphical or textual format, the user's view enhanced beyond the normal experience. The addition of such computer generated information (Virtual objects) can help in the performance of several engineering and scientific tasks. For this main reason, it remains to be research area for many years. AR is not as same as Virtual Reality (VR) since it completely replaces the real world. It can also be stated as the real world is supplemented with virtual data and thus virtual and real objects coexist in an augmented surface. Major advantage of AR is that the view of the real world is used as a background for displaying superimposed virtual data.

An AR user needs to overlay and create a object that needs to be enlarged onto the real world environmental view. At the same time, by bringing the visualization onto the real world, the user will become part of the AR experience and hence, they can interact with both virtual and real objects. Physical interaction in AR is different from animated work, since the virtual object is superimposed on to reality. Advancements in AR are related to tracking and detection[1] but the tangible interaction with the virtual objects in AR surface is limited to touch-screen and it remains a challenging and emerging area to have a interaction between the augmented surface and user. Initially, Image processing techniques were used for gesture recognition using a single camera. Later on it was extended to touch based direct physical interaction but still there exists an occlusion in user's view.

System design: The system design describes the general AR work flow (Fig. 4) to display the virtual object using an Interaction Engine. Initially for displaying virtual information over the Target image, can be made by mapping a particular object to it. When an image target is tracked or detected by the application, object that is mapped gets displayed virtually over the image target. The virtual object position and size in the target image should be distinct in such a way that object should be exactly rendered on the target. Next step is to touch, move or to rotate the virtual object; Movement of the object can be done using scripts written in C# or Java. This would control the motion or behavior of the virtual object[1]. It requires getting the current location or position of the virtual object on the scene based on the camera pose. Vision based tracking usually shows the camera image as background and superimposes the objects into the image. Therefore it is always a need to gain the location or position of the camera in relation to the object that is to be augmented. The 6 DOF of the camera have to be determined. These are all referred as extrinsic data. The parameters which incorporate the behavior of the lens, can be referred as intrinsic parameters.

System determines the pose and it is passed to the 3D engine which renders the objects to be superimposed on the camera tracked image. Hence, by knowing the extrinsic data and it's characteristics the 3D engine can

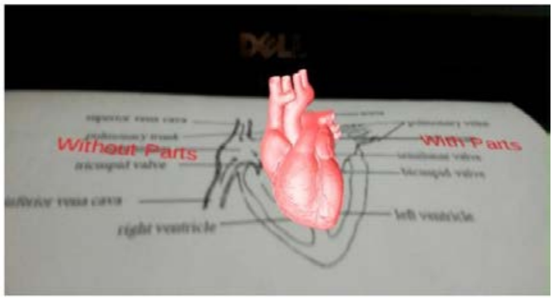

Fig. 5: Displaying human heart (virtual object) over the image target (book image)

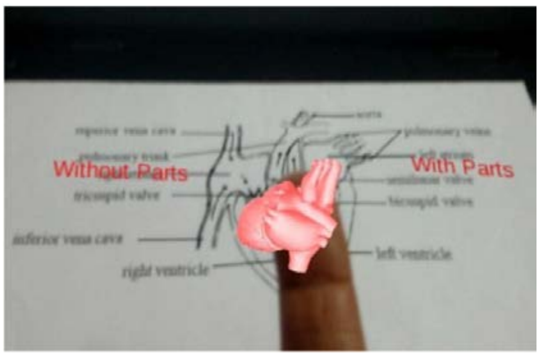

Fig. 6: Displaying rotated view of human heart (virtual object) on interaction

virtually take the same position as the real camera preview. The coordinates of both virtual and real World have to be congruent.

Implementation: Implementation of science based learning AR application for school students is the main objective of the paper. This proposed work focuses on Biology book of 12th standard students. Having AR based Biological structure for learning process makes the students to learn Science in an easy and interactive way. By presenting the concept in graphical format, makes the view of user to be enhanced. Application includes three modules. Initially display virtual imaginary object over the target image. Second, Displaying object with Parts. Finally rotate the virtual object along y axis (physical interaction) when it is touched.

Virtual Button (VB) is used for Initial Touch-based Interaction [9]. When the object is touched or occluded in the view of camera, can trigger an Interaction event with virtual object in the screen. Figure 5 shows the virtual object-human heart over the target.

Touch-based Interaction with the object is depreciated in Figure 6. When the object is touched in camera view, it initiates an event and starts its rotation within the AR surface. Touch is being recognized and

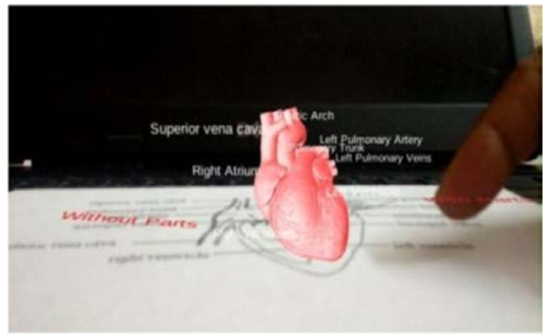

Fig. 7: Displaying human heart (virtual object) with parts on clicking with parts (virtual text)

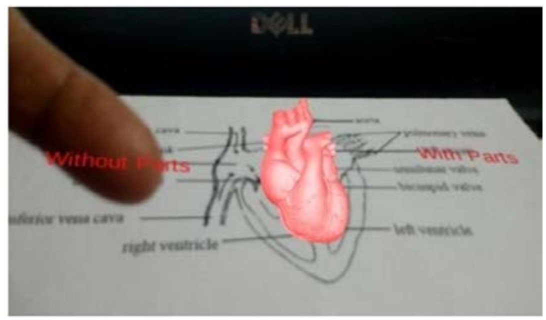

Fig. 8: Displaying human heart (virtual object) without parts on clicking with-out parts (virtual text)

initiates its rotation along y axis. Figure 7 and 8 show the Human heart model with and without parts on clicking virtual text. Hence, on clicking it, respective response is created or triggered.

RESULTS AND DISCUSSION

School Students were asked to use the Interactive based AR app and their view towards the APP was obtained through the Section B of the Survey conducted. Section B includes the following survey questions:

- Q1: I prefer AR app based lessons approach over the traditional approach
- Q2: I found the AR app based lessons approach to be easy and understandable
- Q3: I found the traditional presentation approach format to be easy and understandable
- Q4: I was more motivated to learn new things when using the AR app based lessons approach
- Q5: I retained concept better when the information was delivered via the traditional presentation approach

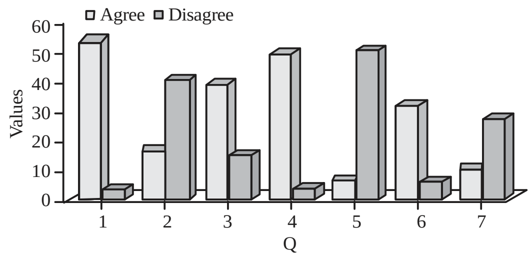

Fig. 9: Survey on augmented reality based learning

- Q6: The classroom experience was more enjoyable when AR app based lessons approach were used

Figure 9 shows the results of AR-based learning approach. The results of the survey clearly conclude that students prefer AR based visualization approach to that of traditional. Students feel that AR-based APP to be easy and they get motivated to learn new thing while using AR Science APP.

CONCLUSION

Thus from the Survey of Traditional Teaching and AR based learning app conducted from the Students, it can be concluded that AR based learning will be more interactive and will be next level user experience in learning. Interaction based learning would be more effective and knowledge gaining process, since the Students are able to view and interact with things through Smart phones which they learn in books.

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