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AREL – Augmented Reality–based enriched learning experience

A V Geetha[1], T Mala[2]

[1] *Research Scholar, Department of Information Science and Technology, College of Engineering, Anna University, India*
[2] *Associate Professor, Department of Information Science and Technology, College of Engineering, Anna University, India*

ABSTRACT
In present era, teaching occur either on a chalkboard or on a projected power point presentation on the wall. Traditional teaching methods such as blackboards and power point presentations are being phased out in favor of enriched learning experiences provided by emerging edtech. With the closure of schools due to COVID-19, the demand for online educational platforms has also increased. Furthermore, some of the recent trends in edtech include personalized learning, gamification and immersive learning with eXtended Reality (XR) technologies. Due to its immersive experience, XR is a pioneering technology in education, with multiple benefits including greater motivation, a positive attitude toward learning, concrete learning of abstract concepts, and so on. Existing Augmented Reality (AR) based education applications often rely on unimodal input such as marker-based trigger to launch the educational content. Hence, this work proposes a multi-modal interface to enable the content delivery through marker and speech recognition-based content delivery. Additionally, the proposed work is designed as mobile based AR platform with the regional language support to increase the ubiquitous accessibility of the AR content. Thus, the proposed mobile AR based enriched learning (AREL) platform provides a multi-modal mobile based educational AR platform for primary students. Based on the feedback received after the usage, it is observed that AREL improves the learning experience of the students.

Section: RESEARCH PAPER

Keywords: Augmented reality; learning technologies; education; Vuforia

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Corresponding author: A V Geetha, e-mail: geethu15@gmail.com

1. INTRODUCTION

Within few months, the pandemic of coronavirus illness 2019 (COVID-19) caused by the novel virus SARS-CoV-2 has forced enormous changes in the way businesses and other sectors operate. According to World Economic Forum, 1.2 billion children in 186 countries were affected by school closures, as of March 2021 [1]. Moreover, the new wave of cases in several regions of the world impacts the return towards normalcy. Herd immunity and vaccines provide only temporary relief to regions affected by the new virus strains. Thus, online learning has evolved into a viable alternative to traditional classroom-based learning, with instruction delivered remotely and using digital platforms.

Even before the COVID era, there is a steady increase in the growth rate and adoption of technology in education. According to GlobeNewswire, it is estimated that the online education market will reach $350 billion by 2025. In addition, concerning the response to COVID-19, several online education platforms such as DingTalk, have scaled their cloud services by more than 100,000 servers [2]. Augmented and Virtual Reality (AR/VR), the emerging technology trend, can improve the online learning experience by increasing engagement and retention.

VR headsets such as Google Cardboard (GC) have made the technology accessible to most of the world's population. VR and AR based online learning platforms offer experiential learning, where the students learn through experience rather than through traditional methods such as rote learning. Some of the benefits of experiential learning are - accelerated learning, engagement, understanding of complex concepts easily.

Traditional educational methods are progressively becoming digital, due to technological advancements. Mobile Augmented Reality (AR) is the superimposition of the virtual objects over reality. AR is widely used in many field such as manufacturing, robotics, behavioral treatment, aircraft engineering design and so

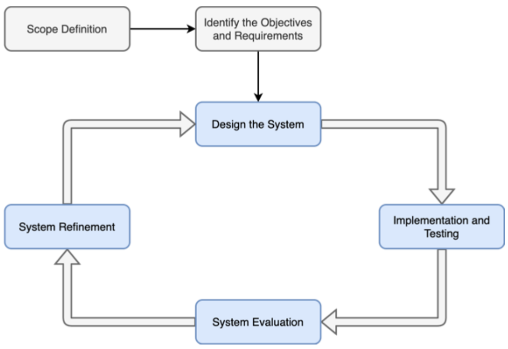

Figure 1. RAD Development Model.

on [3]. The spectrum of Extended Reality (XR), which refers to the spectrum of real-virtual environments. XR has gradually evolved in the realm of education, revolutionizing pedagogical practices as well as students' educational experiences by facilitating the understanding of complicated aspects in education through the visual depiction of images based on real-world data [4]. Specifically, AR and VR has been extensively used in many educational applications. For example, In [5], a solar system mobile app is designed to test the knowledge retention of college students. In [6], a collaborative augmented reality system is used to deliver geometrical concepts in mathematics, which are abstract can be easily illustrated using AR platform. As a result, AR aids in the comprehension of challenging concepts of the learning module.

In [7], the work presents a gesture-based AR system to aid in understanding the anatomical structures of the human body. [8] focuses on the concept of comic-based education through markerless AR for improving metacognitive abilities of the students. Thus, there are variety of approaches for designing the educational apps based on AR and VR such as head mounted displays, markerless systems, and gesture-based systems. In addition, Mobile AR systems are effective because they allow for portability and easy access.

Therefore, the proposed AREL system is a mobile AR-based learning platform in which students can scan the contents of their books to discover videos that appear magically over the pages, transforming a plain textbook into a book with dynamic information. Furthermore, AREL delivers the contents in regional language of the students to improve the engagement with the app. AREL is made up of a collection of modules such as speech recognition system, image tracking and registration module that take advantage of mobile sensors and computational power. The application is developed using Unity Engine and Vuforia SDK.

The mobile application interfaces with the Vuforia cloud target recognition system via a client-server architecture. To grab students' attention and increase their learning experience, the content in the book is enriched with augmented graphics, animations, and other edutainment features.

The mobile camera is linked to the scene's virtual camera as soon as the program is launched. Once the target image is recognized with the help of the Vuforia image database, using pattern recognition algorithms, the corresponding output view is rendered using the display unit. As a result, the output view consists of virtual objects laid out over the real-time objects. The triggered audio output explains the concepts that are scanned, which in turn improves the experience of the learning.

The learning module also consists of multiple-choice questions on the contents taught, to assess the understanding of the learned material. Based on the feedback received after the usage, it is observed that AREL positively improves the learning experience.

2. METHODOLOGY

AREL is designed as a multi-modal AR interface for students to deliver mobile-based learning. Based on the survey of various literature related to AR based educational platform design, it is observed that AR-based learning platform improves engagement and comprehension of difficult concepts. AR also provides an experiential learning experience rather than traditional methods such as rote learning or instructor-led learning. AREL is designed as a mobile-based AR system for increasing the accessibility of AR based learning for students. Thus, AREL complements and improves the online learning solutions or protocols developed during the COVID era.

2.1. Development Model

AREL is developed using the Rapid Application Development (RAD) Model, as it accelerates the system development. RAD model is appropriate when the product development time is less, and the project requires high component reusability and modularity. Figure 1 illustrates the RAD model followed in the work. The RAD model involves four development phases, and they are briefly explained as follows:

- Requirement Gathering: In this phase, the objectives and requirements for the products are gathered based on the technical review. Thus, this phase aids in the understanding of the project goals and expectations.
- User Description: To design the component, the developer collects the description of the component design from its user. Based on the design from the user, a prototype of the application is developed, which further reviewed, and the design is updated.
- Implementation: In this phase, the developer implements the requirements and perform testing on the product. For a typical AR application, this phase involves: UI interface design, creation of 3D objects, coding and testing of the product.
- Evaluation: Once the product is completely developed and tested whether the user expectations are met. Once the product is successfully evaluated, the project reaches the users.

2.2. Software Used

- Unity: Unity is a game development engine which is used to create games for 3D environments such as VR and AR. Unity supports scripting through C# [9].
- The applications developed using unity can be exported to platforms such as iOS, Android, or desktop platforms like Windows. Unity provides a comprehensive framework for adding interactive animations, audio and physics based logical simulations for natural and close to real interactions. Therefore, AREL is designed used Unity engine.
- Vuforia Software Development Kit (SDK): Vuforia is an SDK supported by Unity and enables creation of AR applications for mobile [10]. It uses computer vision-based technologies to track image targets, object-targets, or area targets for marker-based AR application.
- Upon recognition, the virtual object is placed relative to the marker and the virtual camera position. Vuforia is integrated

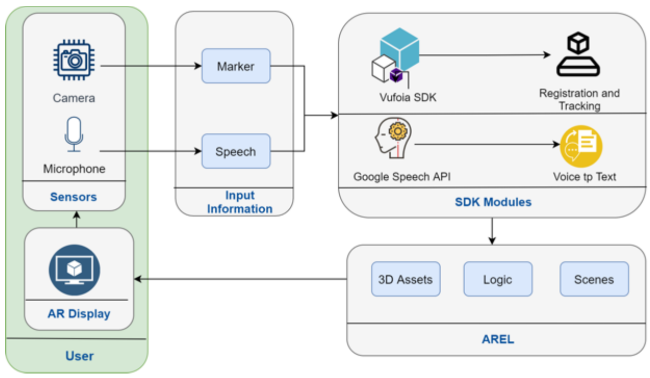

Figure 2. Architecture of the AREL System.

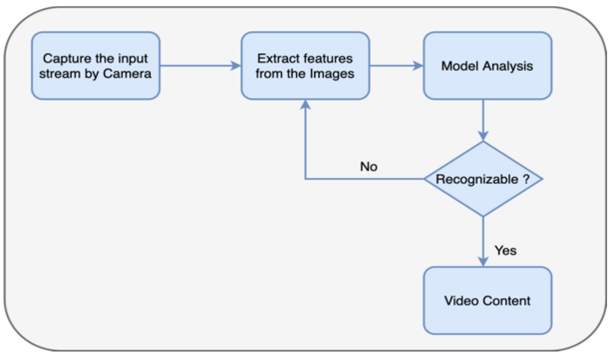

Figure 3. Image target-based content delivery.

to the unity engine for developing the AR concepts of AREL.

- Google Speech-to-text API: The google speech to text API [11] enables integration of the speech recognition ability into to variety of applications.

Upon sending a voice audio, it sends a transcript of the audio from the service. It uses sophisticated deep learning models ranging from Long Term Short Term-Recurrent Neural Networks to sophisticated speech recognition algorithms to perform accurate recognition.

3. AUGMENTED REALITY BASED ENRICHED LEARNING

The objectives of the AREL system are as follows:

- To design a mobile-based AR system which increases the accessibility of AR based learning for students
- To design an AR platform that can act as teaching aid for the students
- To complement and improve the online experience through AR
- To provide multi-modal interface and regional language support.

The objectives are achieved in AREL through its multi-modal interfaced content delivery methods. AREL consists of two modes of content delivery as follows: a) Image target-based content delivery b) Speech-to-text based content delivery. This is illustrated in Figure 2, where the application receives input from the camera and microphone to deliver the content via AR.

3.1. Image target-based content delivery

The AR interface of the system is developed using Vuforia SDK and uses its image target database system for processing the image targets. The image-targets from the children's textbook is created and the processed in the target database system of Vuforia. It is then integrated with the application through unity gaming engine.

Upon scanning these image targets, the virtual camera performs an image recognition based on the features available in the target database. Once a matching image target is found, relevant content is displayed as AR content.

Figure 3 illustrates the image-target based content delivery. The output view consists of video content or 3D objects (with audio description) laid out over the real-time objects.

3.2. Speech-to-text based content delivery

AREL also supports speech-to-text based content delivery. The audio samples received from the microphone is pre-processed using noise cancellation and the speech input is sent to the speech-to-text service. Speech processing involves several steps, including analysis, feature extraction, modelling, and testing. The feature extraction process extracts unique features of the audio using Mel Frequency Cepstral Coefficients (MFCC) technique.

Upon recognizing the sample, the speech input is converted to text. If the text matches any speech commands, then the appropriate AR content is displayed. The detailed steps for the content delivery here is as follows:

1) Record a short audio from the user's microphone
2) Convert the audio into wav format
3) Upload the file into the google server
4) Once the uploaded file is processed, it receives the output from the JSON file.
5) Process the JSON file with the text command, the corresponding number is displayed

Figure 4 depicts the working of the speech to text-based content delivery. Algorithm 1 depicts the process involved in the speech-to-text based content delivery.

Algorithm 1: Speech-to-text based content delivery

Input: Microphone Audio (A)
Output: AR Content based on speech

1: C:=command_words
2: W:=convert_audio_to_wav(A)
3: text_from_speech:=speech_to_text_API(W)
4: If text_from_speech $\in C$ then
5: command= text_from_speech $\cap C$
6: load_content(command)
7: End If

4. RESULTS AND DISCUSSION

AREL provides an AR based multi-modal audio-visual AR based learning with regional language support. To evaluate the usability and the learning experience of the AREL system, an observation study of the prototype system is made in a primary school in Chennai, India. Participants of this study range from 5-8 years. The students were instructed on how to use the app over their physical book. During the experiment, the children were asked to try both the speech mode of learning and image target-based mode. The screenshots of the image target-based content delivery are shown in Figure 5. The screenshots of the speech-based content delivery are illustrated in Figure 6.

During the analysis of the AREL experiment, the children were tested for the concepts presented. It is observed that after

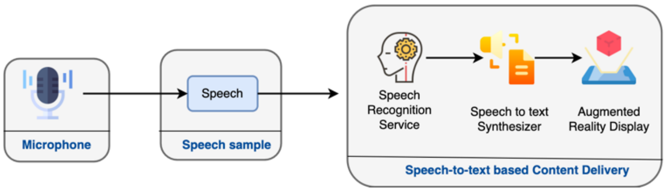

Figure 4. Speech-to-text based content delivery.

the usage of the AREL the children improved and answered correctly. Post the experiment, the parents of the children were asked to provide feedback on the usability, learning retention, learning engagement and overall experience. The result of the survey is aggregated and tabulated, as shown in the Figure 7, where 1 represents the lowest rating such as unusable app or poor learning retention or improper learning engagement. Overall experience of 10 represents a user-friendly design and development with parameters related to learning are score high.

The average usability rating of the app is 7, which represents the user-friendliness score of using the application. As the application supports both voice interaction and image-based interaction, it aids in better exploring their book. The children were excited to see the virtual content appearing in real-time over their book.

According to the results of the experiment, the multi-modal user interface with image-target and voice-based interactions, as well as the augmented reality display integrating real and virtual items, functions as a natural immersive experience for children. As the children try out the various interactions of the same learnable content, the learning retention got improved, as indicated by the tabulated score in Figure 7.

The children expressed a strong willingness to explore the application, indicating that it might be used as a fun and engaging learning tool. This is also indicated by an average learning engagement score of 8.33 from the survey. The overall experience of the mobile AR platform is at 8, which indicates the learning experience and usability experience of the children is positive and improved.

Figure 5. Screenshots from Image target-based content delivery.

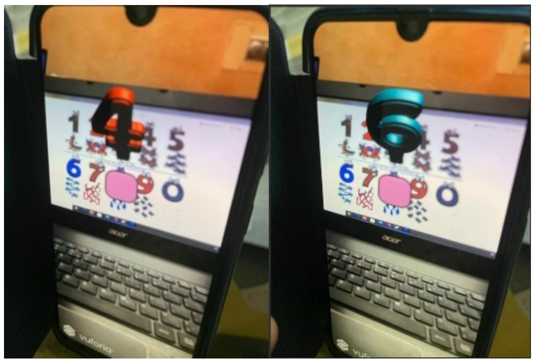

Figure 6. Screenshots from Image target-based content delivery.

Category	Usability of the App	Learning Retention	Learning Engagement	Overall Experience
Tamil	6	8	8	8
Hindi	7	7	8	7
Maths	8	9	9	9

Figure 7. Feedback for AREL.

5. CONCLUSIONS

The development and evaluation of a mobile AR based enriched learning experience for learning language and math are reported in this work. One of the benefits of an AR learning experience over a standard book is that other intriguing aspects like animation, virtual objects, sound, and video may be included while the physical book is still present. The findings of the study suggest that the existence of such aspects during the learning process generate excitement, learning engagement, and enjoyment. The findings are supported by the answers to our survey questions to the parents of the children. The findings also show that the multi-modal interface of real and virtual things provides a natural immersive experience as well as an engaging and exciting learning tool for this age range. However, after repeated usage of the same book, children may become bored with AREL if they can guess what things will appear. Therefore, as part of future work, including a surprise aspect in the application could make it more enjoyable and engaging.

While each image target-based marker has multiple types of visual content that could be presented, randomising the presentation of such content could surprise the child and can be included as future enhancement. Furthermore, learning analytics of user engagement and learning retention can be utilised to evaluate the user experience, and personalised content for each student will be applied in future work.

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