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Web-based Augmented Reality for Information Delivery Services: A Performance Study

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ABSTRACT

Augmented Reality (AR) is the overlapping of the real world and the virtual world. AR is an evolving technology, and its implementation opens up a new direction to multiple types of information access services rendered to the users. The digital library section of the central library IIT Kharagpur has a rich collection of several items like CD/DVD ROMs, Digital Scanners, and VR Devices. Library developed in-house WebAR programs using “ar.js” that support “three.js” and “A-Frame” for Augmented Reality rendering on the web. This study tried to evaluate web-based AR programs’ performance on mobile devices with low-end hardware configuration supporting WebGL and WebRTC. We conducted quantitative research to find the performance of the web-based AR applications using the four independent variables, namely frames per second (fps), request animation frame (raf), load time (lt), entity object (eo). The paper is also helpful to the academic librarians who think about implementing augmented reality library services with no cost involved. The AR-based information service is beneficial to library users with new COVID norms[1], as the user does not need to touch anything to get the information. Instead, it gets into his/ her mobile device.

Keywords: Augmented reality; A-Frame; Information service; WebAR; COVID norms; Information access & delivery; ECS framework

1. INTRODUCTION

Augmented reality is the blending of the real world with digital objects as visual overlays. This concept is very much useful for information delivery. Let us assume there are microfilm and microfiche in the library, and users need to know about it. In a traditional library environment, library staff is required to provide the necessary information. The library team implemented an innovative web-based augmented reality (WebAR) program. When the user focuses his mobile camera on the AR marker (POI), it plays video and provides the knowledge to operate the device. Various points of interest (POI) are created for such information delivery. Our primary research question is “The designed web-based augmented reality model for immersive information delivery is how much stable in mobile phones with low-end hardware configuration”?. This paper tries to measure the performance of such programs and analysis for their large-scale implementation. Library services are for end-users who will be using them with varied mobile phone configurations. If the model is stable and acceptable, then the WebAR model’s commission will always show more library service innovations.

The authors formed a two-person team to research the current state of augmented reality. During our research, we found the software project is implemented using FOSS A-Frame coding. The structure of our study is in four parts. They are technology selection, device selection, data collection from the WebAR programs, and data analysis for performance evaluation. The authors’ investigations are focused on experimenting with the A-Frame web-based AR platform. Lastly, to evaluate the stability level to deploy the web-based AR technologies in an academic library setting.

Tom Caudell[2] at Boeing first used the term augmented reality (AR) in 1990 while assembling aircraft electrical cables using blended virtual graphics. However, augmented reality had existed since the 1960s when Ivan Sutherland introduced a head-mounted (HMD) three-dimensional display. He designed a “Sketchpad”[3] system that makes it possible for a man and a computer to converse by drawings and to blend transparent wireframe lines in real-time. However, Internet resources[4] became more popular in recent times with the advent of smartphones and smart devices. Smartphones enabled everyone to have an immersive AR experience in the palm of his hand. Internet website resources, mobile apps are another milestone. Millions of users use apps like Pokemon Go, SketchAR, Google Translate, BBC Civilisations AR, and many more.

2. LITERATURE REVIEW

AR program triggers based on (i) marker tracking, (ii) location tracking, (iii) projection, and (iv) super-imposition. Marker tracking primarily uses image recognition features to display virtual information overlaid on specific objects. On the

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other hand, the Markerless applications track the mobile's GPS and display information accordingly. The projection mapping technique[5] uses the projector to project an image onto a surface. In augmented reality, applications superimpose computer-generated digital information of various formats like text, audio, video, 2-D, or 3-D models into a real-world scenario. In its article, author Maria mentions that the virtual three-dimensional (3D) exhibition[6] of a space like a museum or a library allows visitors to navigate the scenario closer to reality. The study shows the importance of virtual 3D models for rare artifacts that deteriorated over the period. AR can bring those virtual objects to life by overlaying them in the real environment. Author Jia Liu defines a virtual image drift localisation and mapping problem, which occurs during the camera motion. This problem is resolved using simultaneous localisation and mapping markerless mobile tracking algorithms[7].

Libraries provide AR-based mobile applications for book stacks identification[8], library navigation, check your suggestion, or identify user faces for authorisation. Paulo experimented with OSAKit and Silverlight to develop client-side AR web-based tracking. Server-side AR for the internet developed from the ARToolKit library[9]. These are some of the early software development packages. In Paulo, experiments found OSAKit Client-side tracking provided higher framerates in comparison to Silverlight solution. Using the Unity 3D game engine and OpenCV library, many marker-based[10] AR applications are available in the manufacturing industry for space measurement. Libraries in the 21st century are gradually adopting technology in every aspect of library activities. These libraries are "Smart libraries"[11], as coined by Aittola.

Today there exist many AR applications used for various library services. The online exhibits[12] of cultural heritage, library outreach, and access to archival information are a few areas where AR implementation will be a great boon to the users. However, the study found some notable AR projects specially designed for the library service. The University of Applied Sciences Potsdam developed myLibrARy[13]. The AR app provides review and location information of the media in the library. The AR-based app called ShelvAR[14], developed by the Miami University in Oxford, Ohio, supports librarians for inventory and to identify books placed in the wrong place. An image-based AR app for mobile devices named LibrARi[15] supports users in finding their way to the bookshelf's desired book. "Special Collections using Augmented Reality to Enhance Learning and Teaching," the SCARLET project[16] developed a marker-based app that uses QR codes and book covers to consult rare library books, historical manuscripts, and archives within the library reading rooms.

AR applications are designed and developed in two ways 1) Android or IOS Mobile app-based and 2) Web-based mobile programs. The mobile apps developed using the Unity app platform, Unreal Engine platform, or others. Web-based mobile AR applications developed using A-Frame, AR.js[17], and three.js[18] using the E-C-S framework.

"A-Frame[19] is a web framework for building virtual reality (VR) experiences. A-Frame works on top of HTML, making it simple and extendable. A-Frame core is a robust Entity Component System framework for the web. Thus, it provides a declarative, extensible, and composable structure to "three.js." AR.js is a lightweight library for Augmented Reality on the Web, coming with features like Image Tracking, Location-based AR, and Marker tracking."

3. RESEARCH QUESTIONS

We have done exploratory research on the immersive AR library environment for providing better services to library users. The research questions are:

- What framework makes an AR program more scalable?
- What are the main factors in the performance of WebAR? What is fps, raf, lt, and eo variable's role in WebAR programs performance?

3.1 Library Profile

IIT Kharagpur is the first IIT of all in India. It was established in the year 1951. The library started in a small room of the old institute building named Shahid Bhavan[28]. For the past 70 years, the library has been the lifeline for academic and research activities. The library caters to the need of the 14,000+ users: faculty members, staff, students (UG, PG, Research Scholars) of the 19 departments, 16 centers', 13 schools, 2 Academy, and 12 research facilities[29] of the institute. The library is the first library in India to get ISO 9001:2015 certification[30]. The quality management system applies to library users, and the scope is "Provision of Library Services." The library has a vast collection of 3.5 lakh+ hardbound books, 26,000+ online full- text journals, and 135,000+ e-books. The recently established innovative "Immersive Digital Library"[31] facilities enable users to access various AR/ VR programs.

3.2 Objective

Based on the research questions following are the main objectives of this study:

- The immersive WebAR technology selection and implementation be under study;
- To investigate the web ECS framework of WebAR application be under study;
- To analyse the "Framerate and Entity Object Load Time Metrics" of WebAR using a data mining approach.

3.3 Hypothesis

- There is a significant difference in the framerate of WebAR programs in multiple mobile devices be under study.
- The performance of the AR application is independent of framerate and load time matrices.

4. METHODOLOGY

WebAR programs are beneficial to library patrons for information display. We have undertaken this study to investigate the acceptable performance parameters of the WebAR model. Henceforth to do the research study, we followed the simulation research approach, which involves constructing a WebAR environment within which the performance data is generated. The simulation approach was best suited to

Table 1. Comparative study of various AR software platforms and A-Frame WebAR

AR software name	Support service	Light weight	HWD requirement	Cross-platform	Hosting platform	Development process	Technology
Wikitude	Paid	N	Average	N	Cloud	Easy	APP Based
Spark AR	Paid	N	Average	N	Cloud	Easy	APP Based
ViewAR	Paid	N	Average	N	Cloud	Easy	APP Based
Gamar	Paid	N	Average	N	Cloud	Easy	APP Based
Augment	Paid	N	Average	N	Cloud	Easy	APP Based
A-Frame WebAR	Free & open community	Y	Low having WebGL and WebRTC	Y	Onsite Server	Technical skill needed	Web-Based

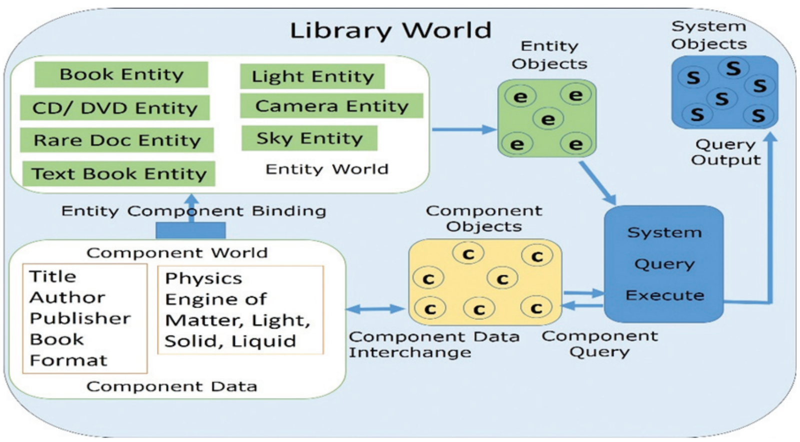

Figure 1. ECS framework of library world.

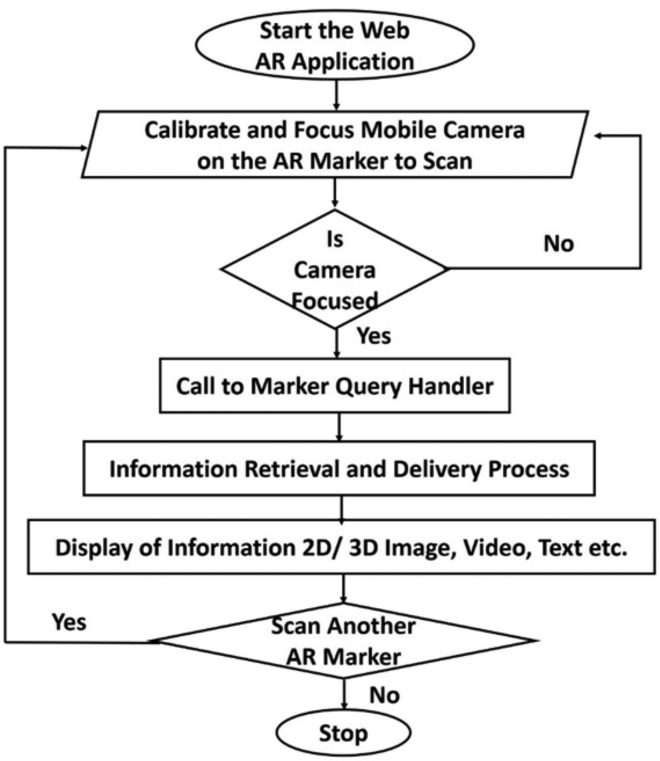

Figure 2. Information access flowchart of WebAR software.

test the performance of a web-based AR model. The simulation research approach used for the simulation of technology is mainly made for performance tuning, optimizing, testing, training, education, etc. We have tested the programs on three devices and tried to collect the data. One simplified model was made to capture the generated fps, raf, and lt data. That is then executed for every device. The study used the observation method for the data collection while experimenting with WebAR programs' execution on various smart devices.

The research study is conducted in three aspects: The first part of our research is technology selection. The study made a comparative evaluation among software platforms necessary to build our testing environment. We have used the ECS framework to create the library world. The framework designs the various entities and their binding components within the library world's boundary. Device selection is the next important aspect because it helped us determine what type of devices will be used for testing purposes. Finally, we used the observation methods for data collection and data analysis for the model's performance evaluation. The study used the statistical model to find the WebAR application performance using framerate rendering metrics. We have observed, analysed, and reported the simulation model. Finally, the performance is correlated using load time metrics, and the data mining is done using MS Excel software.

4.1 Technology Selection

The study compared various AR software platforms like Wikitude, ViewAR, Gamar, Augment, and A-Frame WebAR. The parameters (Table 1) support service, lightweight, hardware requirements, cross-platform, hosting platform, development process, and technology studied for comparison.

The comparative study of various AR apps platform and browser-based AR programs show that A-Frame based applications have many merits. The main attraction is a FOSS web-based cross-platform application that runs on any browser. It functions on all mobile devices having WebGL and WebRTC without any specific hardware requirement. Therefore, the team selected A-Frame integrated with ar.js is for the software development process.

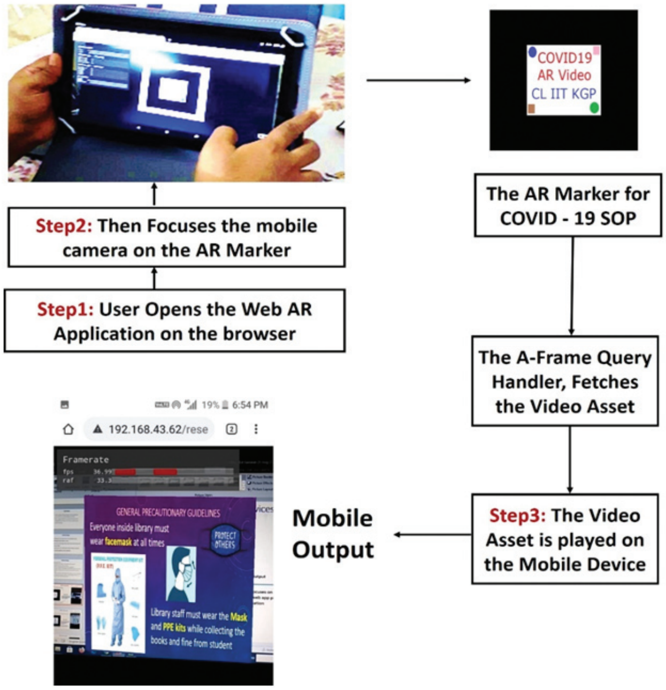

Figure 3. Steps to display WebAR video information.

4.2 The ECS Framework

The library develops a sustainable AR web application using "A-Frame" coding to allow patrons to access library information safely and effortlessly. 3D immersive environment primarily uses the ECS architecture[20]. The immersive environment scene comprises entity objects. Every entity has one or more component, wherein the components stores the data. For example, the book object's shelf location is updated regularly at various events (Fig. 1). Other systems then use this status information.

ECS framework shows the library entity world comprises Book, CD/DVD, Sky, and Camera. The component world contains the item title, author, and publisher as component data. These entities bind to the component object during query system calls like a video handler[21] to play video. The data is stored and mutated in the component objects. During the execution time, the entity object functions along with its bounded component object. The system adds, removes, or mutates the entity and its component according to the need during runtime.

4.3 WebAR Digital Library Services

User's visits the digital library to access varied digital contents. In general digital library staff provides information related to the contents. It is indeed an innovative idea to implement AR technology for information delivery service[22]. Sandra Avila mentioned that AR could attract users by providing additional information. The subject librarian[23] can use the technology for outreach to its users.

To fetch real-time data, users need to browse the WebAR application (Fig. 2) and then focus the mobile camera on scanning the AR marker. This triggers the query handler, which response by showing the immersive video or the 3D image.

The in-house software development team designed a landing page where all the AR App icons are available (Fig. 3). The user has two choices: either scan the QR code for getting the URL or browse the landing page directly [URL https://library.iitkgp.ac.in/pages/con/imlib/ar/index.php]. Then the users select the required program icon. This invokes the mobile camera, and the user needed to focus on the desired AR marker for information. We decided to simulate the four WebAR services for our study.

- AR1 - COVID SOP Information Service for library users
- AR2 - Download COVID19 SOP PDF Information
- AR3 - Displays "Book Ratings" using ISBN code
- AR4 - Displays Information of Online/Offline Database

Author Shimray & Ramaiah[24] made a study on the online portrayal of tribal festival information. Here author showed the screen layout and navigation techniques. The author demonstrated the steps for quick access to online resources. Figure 3 shows the steps to display WebAR video information. The development team designed and developed the online interface is using HTML and JavaScript A-Frame libraries and implemented the prototype model at the central library IIT Kharagpur.

In another experiment [i.e., AR 3], the user focuses its camera on the book's ISBN bar code[25], then the query handler triers the quagga.js library file to translate the ISBN bar code. Then the program fetches the book and rating data using GoodReads API. This a handy tool for knowing the rating of any book on the fly.

4.4 Assessment Methodology

FPS (frames per second) is the number of frames rendered by the application program in one second. We have used the AR framerate and load time metrics of video, image, and text for measuring the performance of the application software. Liu[26] studied the effect of low framerate (FR) on video quality. Liu's study found that less than 30 frames per second (fps) provides a low-quality video and 60 fps is the magic number[27]. This study used the observation method to get the framerate and load time of the AR scene. The selected WebAR scene played on two mobile devices and then recorded the data for analysis.

5. DATA COLLECTION

We consider RAM is a Critical Performance Indicator for the AR program running on the mobile device. So two standard sets of mobile devices were selected for performance analysis. In the experiment, to record the load time, we used a desktop computer. The configuration of the devices used for testing is (i) Device 1 with 3GB RAM, 1.6GHz octa-core (ii) Device 2 with 2GB RAM, 1.4GHz octa-core, and (iii) Device 3 with 8GB RAM, intel i5 2.4GHz, 5Mgpix, 64 bit Win 10 OS.

The WebAR program evaluation is made using the following parameters (Fig. 4):

- Independent variable: frames per second (fps), request animation frame (raf), load time (lt), entity object (eo)
- Dependent variable: performance (p)
- Constant variable: entity object (eo), it is static for every A-Frame scene of a particular WebAR program
- Remark: The study selected four WebAR programs based on the information delivery process. AR1 for

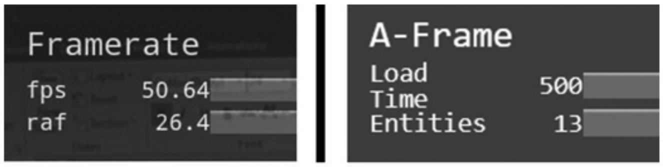

Figure 4: Sample (a) Screenshot of fps & raf (b) Screenshot of lt & eo.

video playback, AR2 for display image and download pdf content, AR3 & AR4 display textual content. Eighty observations were taken in both device 1 and device 2 to record the fps and raf variables, and 40 observations were made in a desktop system for the load time variable. The study considers 90Hz and 120 Hz display refresh rates to be a limitation and excludes them for future scope.

6. DATA ANALYSIS

The display refresh rate with 60 Hz shows 60 new fps. It defines display hardware that can deliver 60 frames in 1 sec. The standard time between two display refreshes is 1000ms, i.e., 1000/60 ~ 16.6ms (GameBench Staff, 2019)[27].

6.1 Performance Testing

Using the independent variables we define the scene functions as fn(fps,raf) and fn(lt,eo). A-Frame scene's standard performance occurs when the fps is between 30 and 60, with a refresh rate of 16.6 ms. The function defined as fn(60,16.6). The study collected ten records for each of the four AR programs. To measure the AR program's performance, we have plotted a raf on the x-axis and fps on the y-axis.

6.1.1 Analysis

- We found that both the variables (fps & raf) are independent of each other, and there is no periodicity. Two records observed in Fig. 5 and Fig. 6 show fps below 30. The study shows a 0.025 per cent of such framerates are responsible for lowering the efficiency performance.
- Both mobiles with 3 GB and 2 GB RAM show similar framerate performance. In Fig. 5 and Fig. 6, frame metrics are between 30 fps to 60 fps, which are considered acceptable performance. Therefore, we found the performance matrices are insignificant to the hardware of the devices. So we found the WebAR program functions on all mobile devices having WebGL and WebRTC with no specific hardware is required

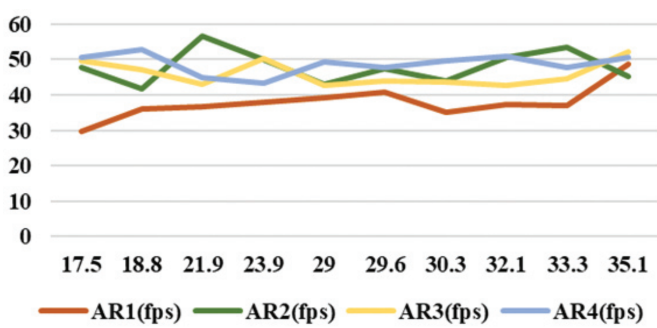

Figure 5. raf vs fps for Device 1.

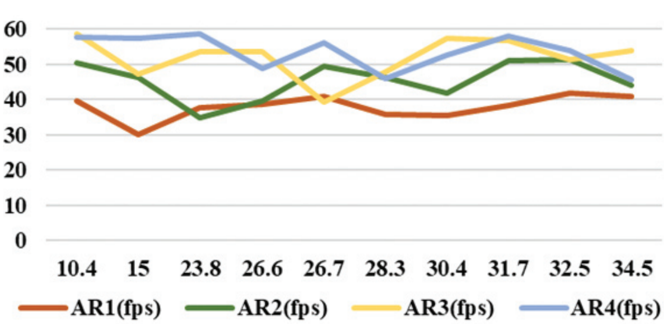

Figure 6. raf vs fps for Device 2.

Table 2. Mean values of fps & raf on mobile devices

	Device 1 Mean (fps)	Device 1 Mean (raf)	Device 2 Mean (fps)	Device 2 Mean (raf)
AR1	37.933	25.99	37.835	27.15
AR2	45.532	20.83	48.016	23.13
AR3	51.944	21.34	45.98	18.73
AR4	53.528	18.44	48.765	20.94

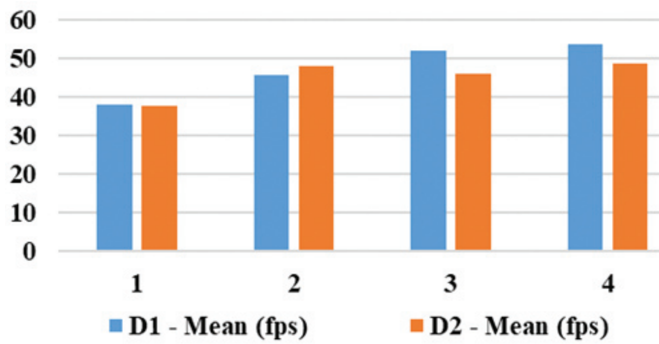

Figure 7. Comparison between device 1 & device 2 for Mean(fps) of 4 AR Programs.

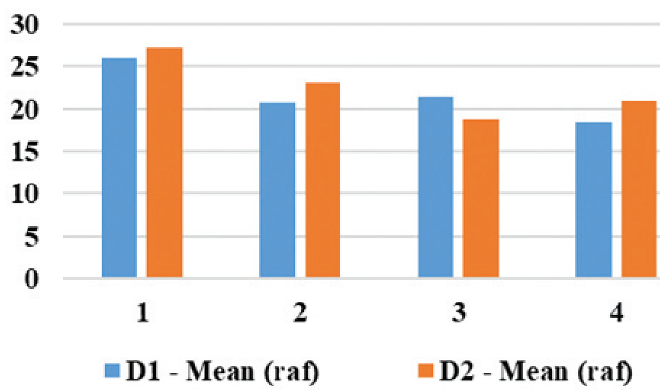

Figure 8. Comparison between device 1 & device 2 for Mean(raf) of 4 AR Programs.

6.1.2 Mean Analysis (fps & raf)

The ideal frame metrics values are 60 fps in 1 second with 16.6 ms refresh time. So we calculated the mean value of fps and raf variables for all four AR programs. (Table 2)

Table 3. Mean values of the load time of WebAR programs

Device 3	**8GB RAM, intel i5 2.4GHz, 5Mgpix, 64 bit Win 10 PC**			
Load time reading	**AR 1 (eo=13)**	**AR 2 (eo=13)**	**AR 3 (eo=16)**	**AR 4 (eo=20)**
Mean	325.1	353.7	580.9	618.1

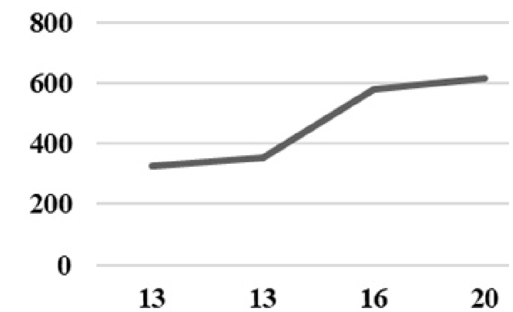

Figure 9. Entity Object (eo) vs Load Time (lt) for Device 3.

Mean AR (fps) = $\dfrac{\sum_{n=1}^{n} AR(fps)}{n}$

Mean AR (raf) = $\dfrac{\sum_{n=1}^{n} AR(raf)}{n}$

We plot the resultant mean values in a bar chart (Fig. 7 & Fig. 8). The study shows no significant difference between the mean fps and raf values of both the devices. Henceforth the null hypothesis is accepted. There are no significant differences in fps and raf of WebAR programs in mobile devices.

6.1.3 Mean Analysis (lt & eo):

This study tried to find out whether the entity objects have any significance with load time. We plotted the mean load time of AR programs and entity objects. We found that with the increase of entity objects in an AR scene, the AR program's load time increases. The calculated mean values (Table 3) are then plotted in the line chart (Fig. 9).

It shows that the performance of the AR programs is directly related to fps and lt. If there is a loss in fps, the video frame performance decreases. Similarly, the increase in scene load time also affects the performance of the program. Henceforth the performance (p) variable is dependent on the two functions fn(fps,raf) and fn(lt,eo).

7. DISCUSSION

This study had considered smartphone memory as a critical part of performance evaluation. We surveyed the market and found that smartphones are available with 1,2,3,4,5,6 and 8 GB or more RAM. The study found that the more RAM, the better hardware configuration of the phone. Devices with 4GB or above RAM capacity are excluded in our study because they are loaded with better configuration. Naturally, those mobiles will have a better performance level. We also conducted a random survey among 170 users to see what type of smartphones they use. Does 2GB and 3GB smartphones are used by any users?. We found 94 users have smartphones with 2GB RAM and 47 users have 3GB RAM. It shows a good number of user uses devices with 2GB and 3GB RAM. Very few users use 1GB RAM phones; those are also excluded in our study. Henceforth we selected two such devices with 2GB and 3GB RAM for our experiments.

8. CONCLUSION

The Augmented reality market is estimated to grow from USD 10.7 billion in 2019 to USD 72.7 billion by 2024, as reported in marketsandmarkets.com. The growth is at a CAGR of 46.6 per cent in the next four years. Smart mobile devices have increased access to AR systems. It is a boon to the library users for accessing the information on the go. AR implementation in academic libraries must be the recent phenomenal change bringing new ways of information delivery. The study found ECS framework of web-based AR programs is scalable for information delivery, such as guided tours, new library event notices for freshers, and media location information. The web-based AR programming using A-Frame, ar.js, and three.js provides a cost-effective solution in today's era. The software programs' performance testing with 2GB and 3GB RAM devices shows the hardware is insignificant regarding the performance. Moreover, we found that performance is highly dependent on the entity object. We observed that the 0.025% framerates are below 30 fps. The real-time WebAR information data fetching for ISBN rating is terrific to experiment with remarkable load time performance. The AR-based information service is valuable to library patrons in this new COVID environment by following the new normal. The user does not need to touch anything to get them a piece of information. Instead, the mobile camera is focused on the AR marker. Data is delivered on the fly, such as guided tours, library fresher's notices, media location information, and many more.

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