Google Cardboard an Epitome of Low Cost Virtual Reality Platform for Heritage Promotion

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ABSTRACT

Tourism has always backed the country's economy even in the most slump period of their economy. Technological advancement is a major adjunct to evolution of tourism, which has led prospective tourists around the globe to plan out their visit to the sites. An extensive survey brought forth drawbacks related to navigation, drawbacks while conveying knowledge by tour guides (Possible human error) and ease of access in existing resources. This paper aides to create virtual reality (VR) platform by subduing the issues, in order to recreate a real like environment to have better insight of the site thereby inspiring its viewers to visit .The application is concocted for virtual tours of India's two most prominent heritage sites: - India gate and Red fort. Google cardboard VR collated along with viewer's mobile device to project virtual tour feature, aides in establishing an experience of the heritage site and its surroundings with comprehensive briefings (Just as a tourist guides), in a free roam mode(Giving navigational sense) from any location. The application also encompasses panoramic videos, 360 stereoscopic views and audio narrations to make it more captivating. The application possess an option of switching between different modes depending upon the availability of VR headset. **.** *Detailed analysis of users opinion based upon factors- Usability(usability evaluation), Comparability (factor comparing knowledge delineated by tour guide and by the application), Practicality(factor stating how gratifying is the system's flow) are recorded for evaluating the effectiveness of system. The developed application can be experienced on both android and iOS platforms.*

Keywords- Google Cardboard, Virtual Tour, Panorama, Stereoscopic Images, Virtual Reality, 3 Dimensional models

1. Introduction

Virtual reality has been around since 1980s **[1].** Due to its gouging cost, the technology has never been used by mass audience. In recent years of computer graphics advancement has made it possible to produce high graphic rendering capabilities with powerful processors to be operated as mobile devices. Being inchoate, this technology was limited to military and scientific uses, but in recent years, development in this field expanded the scope of technology. These led to introduction of google cardboard **[2]** (low cost VR platform), thereby making the virtual reality technology more approachable (Figure 1).

Figure 1 Person enjoying the Google cardboard platform. Source: **[3]**

The tourism acts a major factor for contributing the country's economic growth. With various advancements taking place in the human race, it is the heritage sites that binds us to our roots and depict our culture and heritage .The primary problem for a tourist when visiting a heritage site are 1) scares availability of the relevant information about various locations (navigational and factual information) inside the heritage sites. 2) Non availability of a tour guide with a native and favorable accent or language providing correct information (free from any possible human error due to exiguous knowledge) which is understandable to the tourist. 3) Heritage site may or may not be properly maintained by the authorities when being visited, which can give a blatant impression to the tourist.

The purpose of this research is to provide a perfect blend of virtual reality (Cardboard platform VR) with the possessed knowledge about the heritage site so that it can be showcased as an immersive experience **[4].** This research develops a system which gives a virtual walkthrough of the monument so as to make the tourist well informed about the key aspects of the heritage site as well as giving the navigational sense of the location. The system incorporates huge amount of literature related to the heritage site in the form of collection of informative audios running in the background. Out of which, section specific audios are triggered whenever the user enters a specific area of the site (mimics the work of the guide) along with the ability to choose language of his choice. 3 dimensional model are included in system to provide the user with better insights of the art, giving the clear insight of designs embedded on the buildings giving the user the experience of how it used to look when it was originally constructed. In terms of technical aspects, enhancements are made upon the conventional practices of designing a virtual reality application by associating the movement to the angle of the head mounted device (HMD). Inside the virtual tour, user will start moving in the direction in which he views when the HMD is kept within a certain range of angle and stops otherwise. Panorama images **[5]** and stereoscopic images **[6]** are incorporated to give 360 degree videos. Also, an option of toggling between conventional smartphone view and split screen VR mode is provided in case of absence of Google cardboard VR.

The initial heritage sites chosen for research are India gate and red fort present in New Delhi, India. These sites carry immense political and historical importance. India gate is a memorial to 82000 soldiers that died during the World War 1. The republic day parade takes place at India gate. Red fort constructed under Mughal period is a place where Indian prime minister delivers a national broadcasted speech on India’s Independence Day to address the nation.

The Remaining sections of the paper are segregated to provide information as follows. In Section 1.1, a discussion about the history and advancement of virtual reality. Section 2 conveys the features of the system designs that are incorporated to design an application using this research. Section 3 depicts the overall methodology utilized during the research. Section 4 is a complete analysis of the research to evaluate its capabilities with real application. Section 5 concludes the paper and describes the path for future works.

1.1 Evaluation and related works

The first ever terminology to be coined for virtual reality was in Charles Wheatstone's research on Stereoscopic photos and viewer in 1838. Researches advanced and by 1931 the virtual reality systems started aiding the mankind with researches like "*link trainer*", the first ever flight simulator created by Edward link. When Ivan Sutherland postulated the idea of HMD (head mounted device) **[7],** it revolutionized the virtual reality concept as a whole because of which he is regarded as the "father of computer graphics." Even though the use of HMD was incorporated in 1960's, **[8]** the term "virtual reality" was coined in 1987. It has only been in recent years that platforms like Google Cardboard have made the virtual reality experience more accessible to the general public.

Researches have been conducted in the past to make the heritage tour more interactive **[9] [10].** Douglas M. Klahr **[11]** cited concepts of stereoscopic photography to depict Rome of 1902. Over the years the heritage sites have parted with their original essence due to harsh climate and lack of maintenance. Adeola Fabola, Dr Alan Miller **[12]** worked upon restoration of the original essence by reticulating 3 dimensional models of dilapidated sites. The models even though provided comprehensive knowledge of individual parts of the heritage sites, it lacked the ideology of how these individual parts are interconnected and does not provide the guided tour of the heritage site. Kawai **[13]** formulated about panoramic view interpolation to create a virtual environment for personal computers (PCs) but the system lagged the sense of virtual walkthrough and its scope was limited to PCs which cannot be accessed remotely. Mudenagudi **[14]** designed a system in which user's movement inside the virtual walkthrough were limited (allowed user to look around but not move) and also lagged basic interactive features like audio narration and real images.

Wendy Powell and Vaughan Powell **[15]** discussed the possible ways for navigation namely:- continuous motion, magnetic switch and Bluetooth controller. Incorporating Bluetooth controller will increase the cost of the overall hardware required to operate the application. The single switch present in the VR cardboard is used to navigate within the application (switching between scenes), therefore the continuous motion approach is enhanced to facilitate the user to either stop or move during virtual tour depending upon the angle the VR's gaze makes within the application.

This research advances over the aforementioned concepts by using stereoscopic images and 3 dimensional models to recreate a virtual environment depicting the area of the heritage site. Thereby, preserving the sites values in its original form **[16].** The viewer is facilitated with a choice to roam freely around the area of heritage site according to his own wish and gain knowledge of the area at his own pace. Also the study allows the user to toggle between VR view and unified mobile view (for users without VR headset available).

2. System Features

The application developed provides a captivating experience of the heritage site by utilizing the technology that is already possessed by legions of users in the form of their mobile devices and an additional hardware that is a VR cardboard device which has a very nominal cost. Audio and visual trials are added to provide a precise and apposite information which remains uniforms for all its viewers unlike the traditional guides present at the heritage site which may do some human error at the time of narration. The detailed features of the application is provided in below mentioned section.

2.1 Audio Narratives

Navigational audios are consolidated into the system in every scene which helps the user to navigate through different components and familiarize with the environment of the application. Informative clips providing paramount details are triggered in the panoramic views and at monuments whenever the user comes in its vicinity during the virtual tour.

2.2 Panorama images

360 degree images **[5]** are incorporated into the system. When the user moves the smartphone which is mounted to Google cardboard, the smartphone's sensor detect the head tracking movement and accordingly shows different parts of the image. With the help of panorama images and informative audios running in the background, the user would feel real life like experience. (Figure 2)

Figure 2 Panorama image of India Gate

2.3 Stereoscopic Images

3 dimensional models are imported into the system **[6]** which are mutated to recreate the stereoscopic dimensions of the monument exacting the patterns and designs that were implemented during its construction and have been dilapidated over time. The textures and patterns of the 3 dimensional model are depicted in a way that provides with a greater analysis of depth perception and curves of the monument to the viewer.

2.4 Virtual Tour

The virtual tour is designed to recreate a virtual view in and around the heritage site in which the user could virtually move around places viewing different parts of the heritage site at his own pace. Audio running in the background bestows historical information about the monument concurrently giving a fair idea of navigational sense of the area. (Figure 3 and Figure 4)

2.5 Switching Views

The application is facilitated with an option to swap between cardboard view (split screen) (Figure 5) and conventional smartphone view. (Figure 6) This option can be triggered in real time at any scene and is included to make the application compatible for those users that may not have a VR cardboard. Thereby, strengthening the application to target a larger audience by only compromising for a conventional mobile view instead of a more enamoring VR mode.

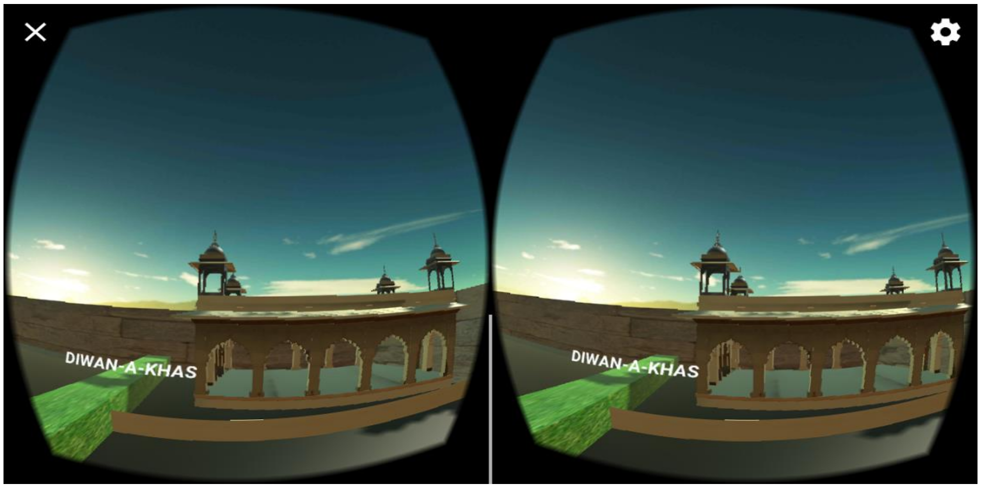

Figure 3 Virtual tour feature (red fort)

Figure 4 Virtual tour of red fort

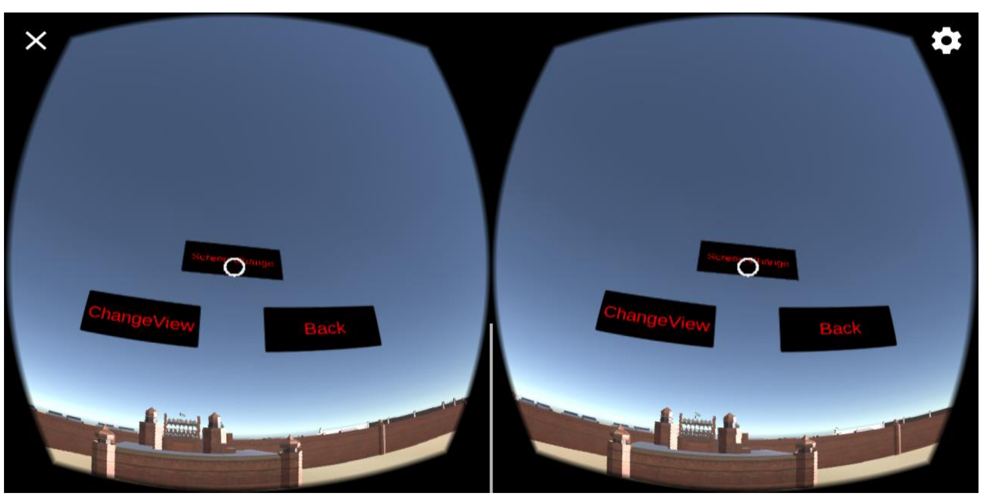

Figure 5 Mobile screen in cardboard view (VR view)

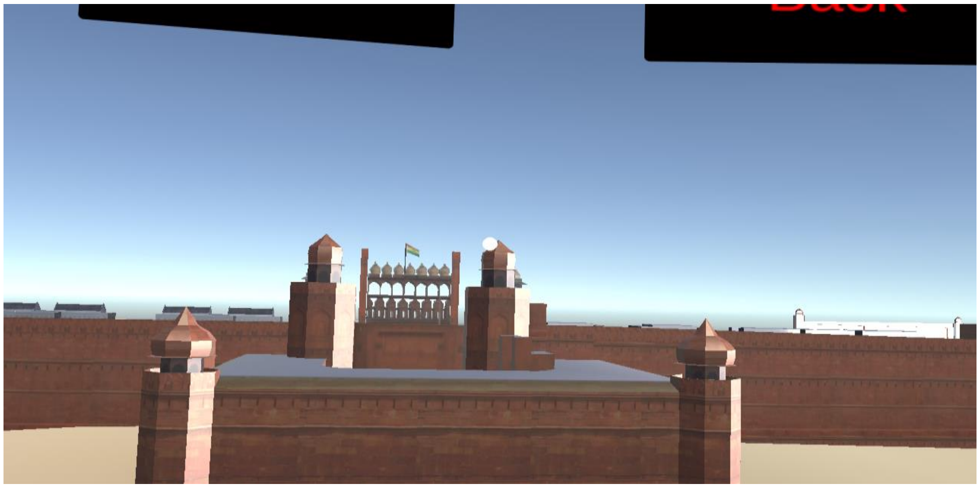

Figure 6 Mobile screen in conventional smartphone view

3. Methodology

This research aims to promote the culture and history of Indian heritage sites. The current systems available are not that easily accessible or there experience is not enlightening enough to attract mass interest. Wherein, the research is concocted to provide an Immersive experience of the monuments to the users. It is provided using 3d reconstructions of the derelict monuments to moderate the effect of damage that the monument had over the period of time and by lack of its maintenance(poor preservation) , 360° image panorama for giving intuitive experience to the viewer with narrations about the site, running in the background, 4 pi steradian video panorama **[17]** for the virtual museum explaining the user about the history and culture of the heritage site backed by the evidences excavated by the Archaeological Survey of India. The research is formulated to provide a system which encompass a virtual tour of the site to provide a real life like involvement of the user that would be experienced while visiting the heritage site. The different locations of heritage sites are incorporated in the system using 3-dimensional models along with informative audios. The prime edifice of the heritage site is assimilated with 360° panoramic images, 3-dimensional models along with informative audios.

The system is designed for mobile devices comprising android and IOS operating systems. These operating systems are targeted as they cover major portion of the mobile industry. The smart phone amalgamated with the virtual reality systems such as Google cardboard **[2]** together acts as a hardware required for successful implementation of the system. The android application uses smartphone’s storage components (to store navigational audios, informative audios, panoramic images and 3-dimensional views), therefore the performance of the application is not hindered (due to loss of network coverage) and is skilled to work in remote areas.

3.1 Hardware

Google provides documentation for designing the cardboard VR headset by providing details related to its design specifications, once the smartphone is mounted to Google cardboard, the user interaction with the device is facilitated by the help of a single touch **[18]** several methods were considered for the interaction to take place.

3.1.1 Magnetic touch

Initial release of Google cardboard documented the use of two magnets, one of which is fixed and the other is movable but in a limited space designated for the button, the movement of the magnet causes disturbance in the magnetic field between the two magnets which is sensed by the user’s mobile phone’s magnetometer as a touch, the limitation with this approach is that a good amount of devices in the market today do not carry an inbuilt magnetometer limiting the amount of target audience.

3.1.2 Physical touch

Google cardboard version 0.9 (July, 2016) introduced the VR reticle to provide an alternative of touch trigger at the place where the reticle points simulating physical touch irrespective of the touch position on the screen, this could have been implemented using materials like sponge, aluminum foil & ruff fiber, each of which other than the touch through fiber carried some limitation depending upon the device screen type.

The touch is triggered using fiber cloth attached to cardboard headset which will be controlled by the user, physical touch approach through fiber has been adopted owing to convenience and cost effectiveness of the approach. (Figure 7)

Figure 7 Assembling of google cardboard

3.2 Software and System Workflow

The system utilizes sensors **[19]** and storage of mobile device for the effective working of the application. The application uses smartphone's gyroscope along with the accelerometer sensor to sync with the scene orientation for tracing the head movement along the designated path. Unity engine **[20]** is used due to its 3-Dimensional virtual environment creation capabilities. The system is developed using C# **[21]** as the programming language.

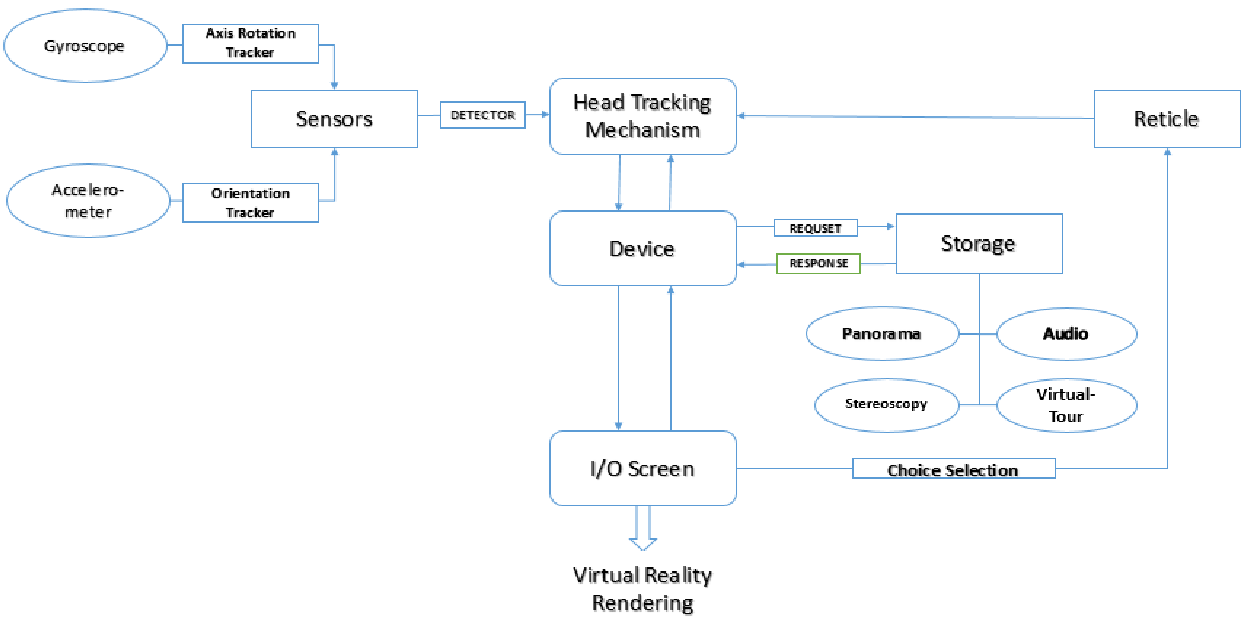

Figure 8 System Architecture

The procedure devised for the development of application is discussed below:-

3.2.1 Stereoscopic environment creation

Existing 3 dimensional models of the heritage sites have been acquired and then mutated into the filmbox format (.fbx extension). These models are then imported to unity environment. The models are scaled and altered in order to accommodate them into the virtual environment system. GVR main camera and directional lightings are calibrated in such a way in the scene that the depth perception is visualized correctly**[22]** The then established view is adjusted according to the cardboard platform in order to provide a greater depth perception.

3.2.2 Panoramic environment creation

Pictures of heritage sites from different angles are compiled and texture type is modified to cubemap. For implementing panorama cubic approach is used **[23] [12],** a wide angle panoramic view is created by placing six different images on the faces of the cube. The GVR main camera resides at the center of the cube and is adjusted according to viewers head movement to display the six faces simulating a 360 degree view **[5].**

3.2.3 Audio narratives

The system contains informative and navigational audios. The informative audios are the ones which would provide the user with all the imperative knowledge associated with the particular location at the heritage site. The navigational audios would guide the user to navigate within the virtual system and understand all its components. Navigational audios are designed by using text to speech software, informative audios are recorded in the native accent to have correct pronunciation of the names and are incorporated in MPEG-2 Audio Layer III (mp3 format). Objects are placed throughout the application to which the audio sources are added and are triggered as and when the objects are called by GVR camera's audio listener.

The portion of algorithm to enable audio narratives in virtual tour feature is mentioned below:

1. Start
2. Set Audio Source component
3. Set Box collider
4. If(!collider->collides)
5. Play Audio Source
6. Else

7. Stop Audio Source
8. Stop

3.2.4 Virtual Environment Creation

To create the virtual environment, Google VR SDK for unity and pertinent plugins are imported by which the smartphone screen is cleaved into two halves, the smartphone then collated with Google cardboard establish the users view. To split the smartphone screen the GvrMain camera is used instead of unity's default main camera. In order to provide a greater depth perception , research into this revealed stereoscopy to be the best approach wherein the left image of the split screen is formed by keeping the focal center at the point of center for the view if it were to be seen in real and the right image formed by keeping the focal shift proportional as 1:3 with respect to the focal length of the lens that are being fitted in the cardboard VR which is researched out to be best when there is 45 mm focal length for lens and 15 mm focal shift for right image as it helps to counter the effect of Pincushion distortion**[24]** by applying Barrel distortion as a counter using this method to provide a greater field of view.

3.2.5 Virtual Tour Creation

To ensure captivating experience, following steps are devised to create the virtual tour :

A 3d plane is created upon which terrain textures are designed and existing 3-dimensional models are positioned upon it with reference to the heritage site's map (Figure 9).

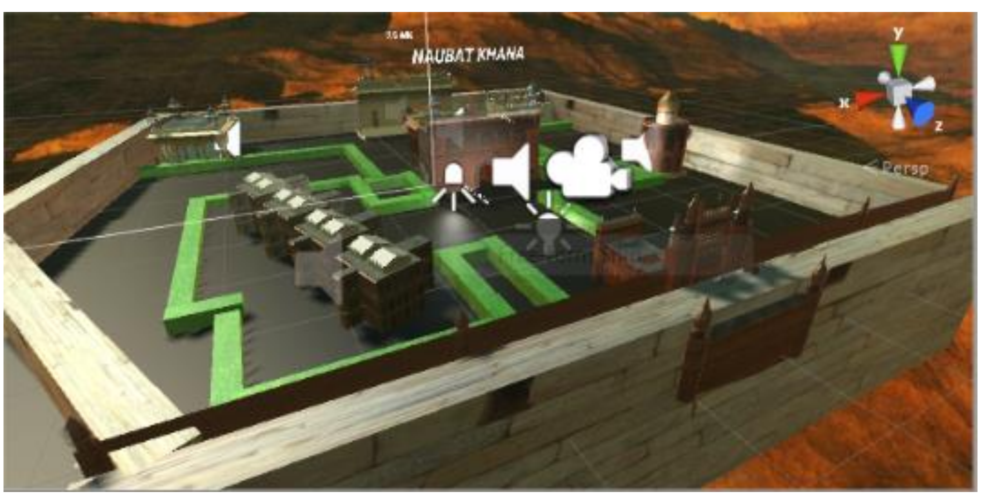

FIGURE 9 3-D plane with terrain and 3 dimensional model positioned

A capsule collider is associated to the GVR main camera which is programmed to provide auto walk at a fixed speed in the direction of the users gaze and is disabled when the ray casted from the GVR main camera collides with the plane. The auto walk movement is restored as soon as ray emitted from camera stops colliding with the plane by altering the gaze direction.

Directional lights are positioned around the terrain to have optimum lighting while streaming the virtual tour.

The box colliders which are associated to game objects are designated to all the parts of the heritage site. The size of box colliders are scaled so that they occupies certain region for a particular part in the heritage site. Apropos audios are triggered when the user is in the periphery of the box collider. (Figure 10)

The portion of algorithm to enable auto walk is mentioned below:

1. Start
2. Set Spawn Point Position
3. Update
4. If(walking)
5. Transform position
6. Transform Camera
7. If (Raycast->hit->plane = true)
8. Stop Moving
9. Else
10. Keep moving
11. Exit

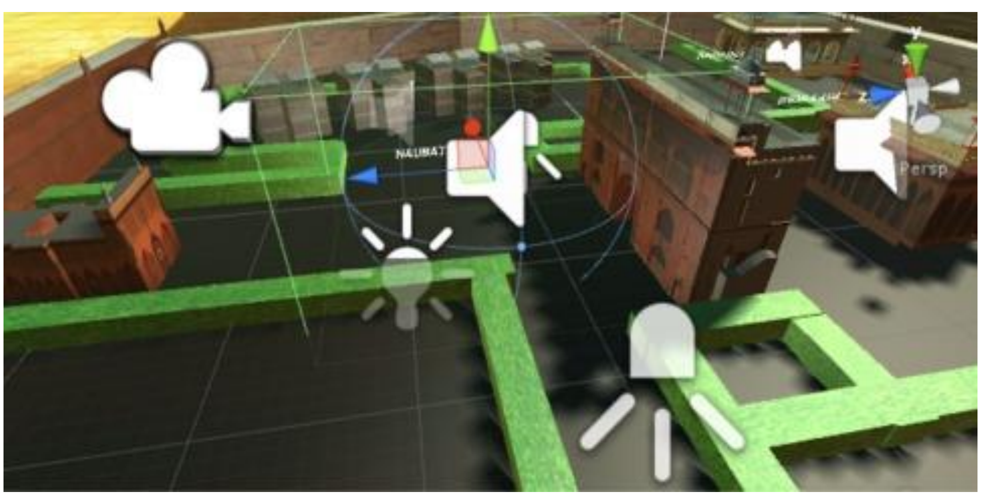

Figure 10 Game object associated with box collider

3.2.6 Menu creation and compilation of scenes

The application involves navigating through a bunch of options in the menu bar and at different scenes by making a choice selection upon placing the reticle **[25]** tracer which is linked to the head tracking movement detected by the Gyroscope sensor present in the mobile device. (Figure 11)

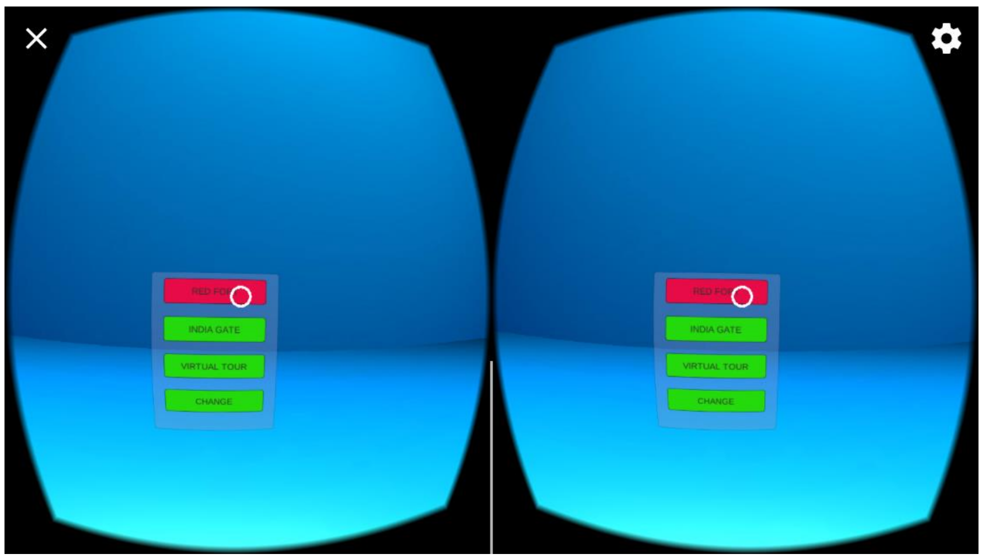

FIGURE 11 Split Screen, Real time change view, Menu bar

4. SYSTEM EVALUATION

The research is primarily conducted to exhibit virtual experience of two heritages sites India Gate and Red Fort. A working porotype is designed on the basis of research formulated. Volunteers comprises of the ones that have visited the heritage sites and the ones that haven't are made to scrutinize the system. To analyze the other user's prospective towards the system a metric was formulated with parameters like

1) Usability using usability evaluation in industry standards devised by J.brooke **[26]** (Figure 12)

2) Comparability, a factor that compares knowledge delineated by tour guide and by the application (Figure 13)

3) Practicality, a factor stating how gratifying is the system's flow in delivering knowledge of the heritage site over the existing system's available in the market (heritage site magazines etc) (Figure 14)

All of above mentioned factors are measured by making the volunteers (with the consent of parents for volunteers under the age of 18) to fill a questionnaire **[27]**. A few participants had a moderate level of prior experience of virtual reality while most of them had no prior experience. The participants were briefed about the working of the system and the purpose of research, only then the analysis was further proceeded. Volunteers segregated into different categories depending upon their ages have different prospective for their admiration towards the application. Volunteers below the age of 18 particularly found the application fascinating and one was recorded quoting the application "*a more interesting history class*". Volunteers among 18-60 found it extremely useful as with the shortage of time with the working age group they can now enjoy the beauty of culture and heritage of the history even while sitting at home. One participant belong to the category of 60+ age group who quoted "*visiting each location of a heritage site at times is very tiresome for me also there are certain locations which cannot be reached by people of my age group easily, this application fills the gap and provides me with a real like experience* ".The volunteers appreciated the feature to switch between VR mode and unified screen mode but almost everyone preferred to experience the application in VR mode**.** Response of all participants were recorded and a breakdown of the results are shown in figure 12, figure 13 and figure 14. Also, the average score of the application in all the three factors (usability, comparability, practicality) remained above the 90th percentile. The users who have already visited the heritage sites has their information being more aggrandized. The cost effectiveness of the cardboard VR headset aided in acquiring the interest towards the application and broadly towards virtual reality approach. The outcomes provided a significant understanding of how the research can widen the attractions, tourism sector can offer. The application runs at 60fps thereby avoiding the distortion/flickering within scenes which is the common cause of dizziness and nausea for head mounted device based applications. Also participants were galvanized by experiencing the virtual reality, which was unknown or thought to be an expensive technology to experience. The active enrolment of volunteers also stated that a developed system will acquire attention of large audience irrespective of the age group they belong.

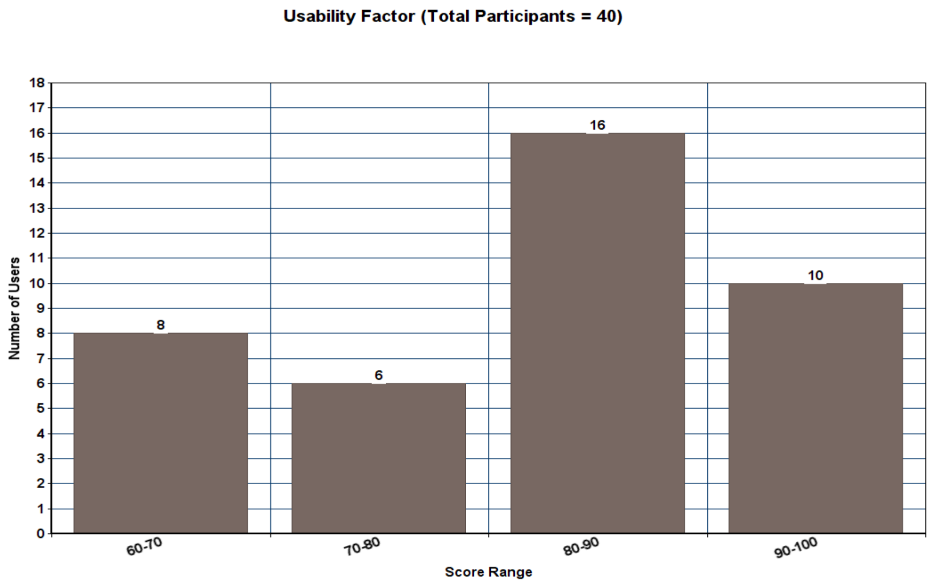

Figure 12 Usability Factor Graph

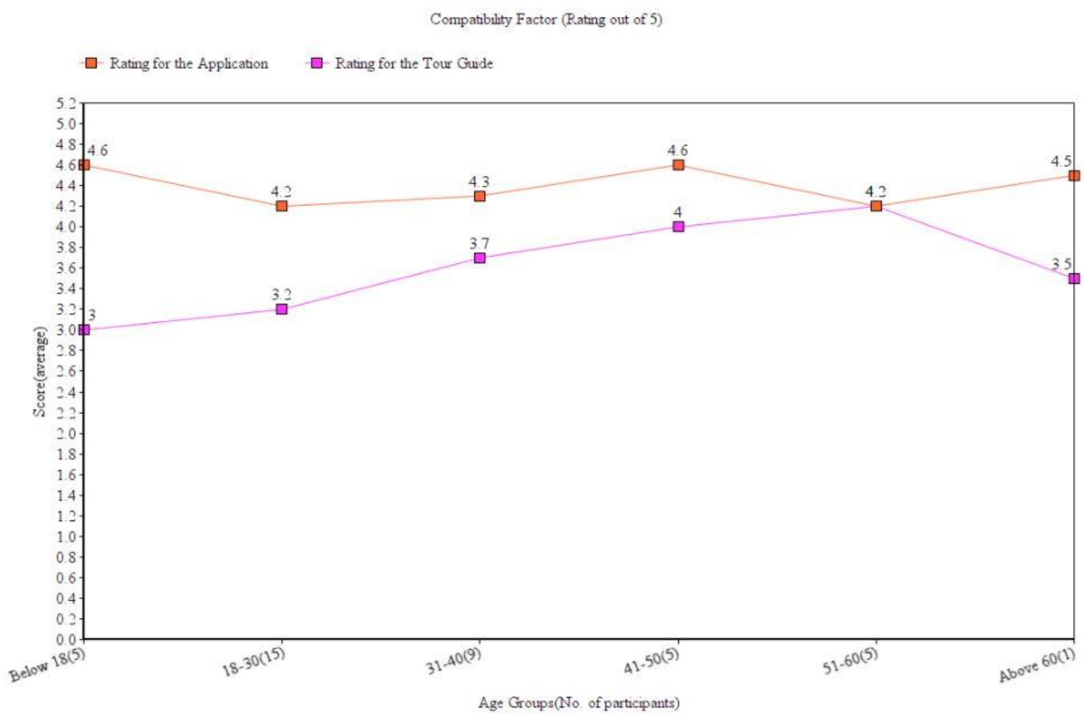

Figure 13 Comparability Factor Graph (Total Participants = 40)

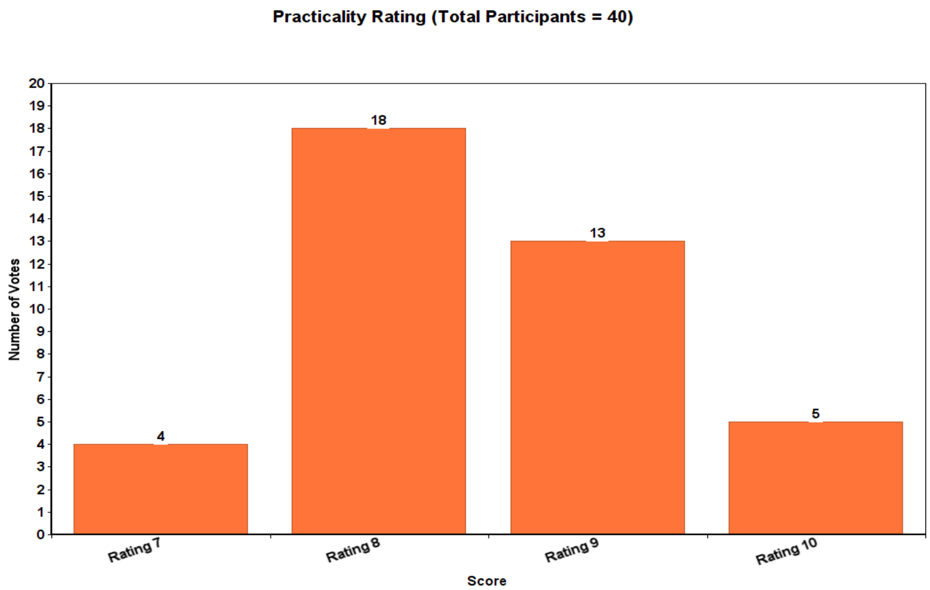

Figure 14 Practicality Factor Graph

5. Conclusion

Several researches have been done to enhance the user experience of the heritage sites but the issues uncovered by these researches are amended by the use of research devised. The construction of the mobile application having the entire content under a single application which provides apropos knowledge thereby reducing the user's effort to gather information from differently scattered resources (websites, pamphlets, books and tour guides). The cardboard VR amalgamated with the designed virtual reality compatible application (formulated based on this papers specifications) revolutionariesed the use of virtual reality concept in the tourism sector which was appreciated by masses because of its user friendly design and cost effectiveness.

The system designs specified in this paper includes the use of gyroscopic sensors (6 axis rotation tracking) for effective head tracking movement as well as to aid navigation between different screens within the application (using V.R reticle function).The application aides in providing a touring guide based knowledge of the area (to mimic a real like virtual tour in and around heritage site at viewers own pace) to its viewer while also detailing the designs of the heritage sites various parts (through 3dmodels and audio narrations) providing a navigational sense. The research parameters: - Usability, Comparability, Practicality on which the system is reviewed by the users for the heritage site proves the effectiveness of the system as it is concluded to be informative ,interactive and easily accessible. The application is accessible from anywhere around the globe and can be viewed in VR mode as well as normal mode (depending upon the VR hardware availability).

6. Future Works

The desired feature to include is the addition of GPS sensors into the existing virtual tour guide feature so as to facilitate geo tagging of various locations inside heritage site so that whenever the user enables the tour guide mode inside application, the GPS of mobile device tracks the location continuously and triggers an informative video regarding the heritage sites location as and when the user enters the locations periphery.

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