Complete The InComplete

An Augmented 3D Re-Construction of Historical Monuments

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***Abstract*— The masterful or chronicled estimation of a structure, for example a monument, a mosaic or generally speaking, an artefact, arises from the novelty and the development it represents in a certain field or in a certain point of time in the human history. More faithfully speaking, more the structure safeguards its unique status, the more prominent its masterful and recorded esteem it has. Consequently, it is our crucial obligation to protect its unique condition, keeping up it as authentic as conceivable over the time. The conservation of a structure can't be constantly conceivable or has not generally been acknowledged, thus, bringing about carelessness, deficiency or even blameworthy reluctance. Thus, shockingly, status of such not superfluous number of structures can run from awful to even calamitous condition. In such a time allotment the present innovation outfits a major help for recreation/reclamation of these landmarks. Therefore, our point is to convey back such structures to its unique authentic condition with the assistance of technology. Among the advanced offices, new conceivable outcomes emerge from the Augmented Reality (AR) apparatuses, which consolidate the Virtual Reality (VR) settings with real world physical environment. This incompleteness we feel while visiting any historical or tourist attracted monument is when we get to see is the degraded or deteriorated remains of that structure and we remain unaware of the original beauty of that monument. The thought is to make a virtual recreation/rebuilding before tangibly following up on the structure itself. We, virtually with the help of augmented reality and image processing we can complete the incomplete structure by drawing on screen when pointed towards the structure.**

Keywords*— *Agumented reality(AR); Virtual Reality(VR); Historical Monuments; Tourism.

I. INTRODUCTION

The solution we focus on is by designing a complete system which includes a camera for the raw data input, an Unity3D environment for processing, Vuforia SDK for augmented reality software development, Blender and Maya for 3D model reconstruction, MongoDB for storage and a centralized server using Spring Framework. The user at the site would point a camera equipped device, in our case a smartphone, to a broken or deteriorated structure which will then be completed in real time. The incomplete parts of the structure are then augmented with images from the database wherein the feature points are evaluated to get an appropriate match. This technique results in more immersive experience of the user into the historical aspect of the structure.

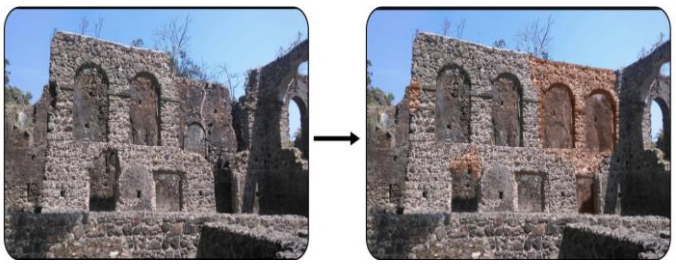

Fig 1. Final Result

II. RELATED WORK

Desai, Nilam's 'Recreation of history using augmented reality'[1] sheds light on augmented reality. Augmented Reality is a technology that composites virtual objects into real world. This perception can be applied to rebuilding of historical object to have realist view of time. Latest technologies associated to cultural and archaeological historical sites have given rise to new concepts such as Virtual History, Virtual Archaeology, Virtual Museums and many more. MAR (Mobile Augmented Reality) can be used that provide way to reconstruct damaged or lost part of heritage sites. Efficient AR visualization scenarios for complementing broken or damaged real objects. This is being used in AR game for Philippine history. Xavier, R. S., da Silva, B. M. F., & Goncalves, L. M. G.[2] in Accuracy Analysis of Augmented Reality Markers for Visual Mapping and Localization talks about an important problem that can be solved by Computer Vision algorithms is that of computing a 3D reconstruction of a scene captured by an ordinary camera. The algorithm to be used here is Simultaneous Localization and Mapping (SLAM). Along

with SLAM using ARUCO marker. The process being divided into two stages, the first stage visualizes the artificial markers are captured and processed. It also produces a map composed of a network of artificial markers that are in global reference frame. In the second stage, images of the camera are used as inputs along with the computed map in an algorithm that localizes each image within the network of markers, thus providing the position and orientation of any camera capturing one or more markers in the environment. Putra, E. Y., Wahyudi, A. K., & Dumingan, C.[3]- A proposed mix of photogrammetry, Augmented Reality and Virtual Reality Headset for legacy perception. The examination on the reproduction of 3D scanned Models was started utilizing photogrammetry procedures and joining of multimedia components. 3D models are shown utilizing Augmented Reality by utilizing Virtual Reality Gear to amplify the experience of the client. It portrays the strategies and procedures utilized in gathering the information and giving development in the perception of social legacy. The outcome is that the framework can give new encounters to clients and a decent 3D perception. Main method used here is 3D-Model Re-Construction using software Autodesk Remake. Images were captured using DSLR cameras and Unmanned Aerial Vehicle (UAV).

III. PROPOSED SYSTEM

Implementation involves Unity3D environment along with various modules with their library supported by Android. Also, a mobile application along with server and database configuration is necessary.

A. Hardware

- DSLR Camera

  A Canon 700D DSLR Camera will be used to get the images which will given as an input to the software for the process of photogrammetry. Photographs will be taken at an angle of 10^{o} from the adjacent click in a 360-degree rotation.

B. Software

- Mobile application

  Unity 3D is a software used for development of three-dimensional and two-dimensional games and simulations. It is also a cross-platform engine for gaming. The Unity Engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins, and games themselves. It also provides drag and drop functionality. The application we are using is based on Mobile Augmented Reality (MAR) using Unity Game Engine. Unity is used to superimpose digital media like image, video, text, sound, etc. on physical locations or objects and can be experienced through electronic media like smartphones and tablets. Unity 3D is easy to design, build, and maintain efficient, reusable, and reliable code.

- Android SDK

  The process to create Android application, running on Android operating system is Android software development. The software kit of Unity includes development tools like debugger and libraries and many more Platform that are supported for development contains computer running OS X 10.5.8, Windows and Linux.

- Vuforia SDK[4]

  Vuforia is a software development kit based on Augmented Reality used for mobile devices. This software is used for creating application based on Augmented Reality. It uses the concept of computer vision which helps in recognizing and tracking images and also simple 3D boxes. The Vuforia SDK helps the developer for positioning virtual objects like 3D models with real world images when it will be seen through mobile phone's camera using image registration capability. Then position and orientation tracking of real time image is done by virtual object which helps the viewer to see the object from image perspective Thus the virtual object appears to be part of real-world image. With this SDK various 3D and 2D targets can be made. Advanced features of this SDK are dynamic image target selection and the capability to construct and rearrange targets sets dynamically.

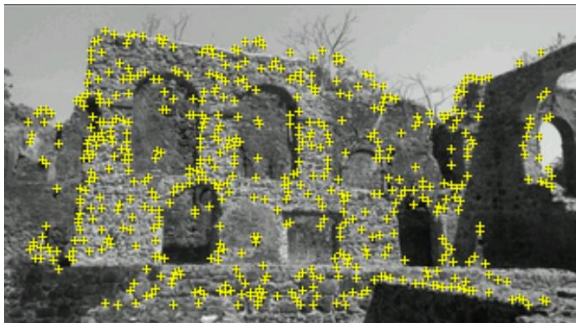

Fig 2. Identification of Key Points

- Server
  - MySQL Database

    MySQL is free and open source database management system which uses structured query language. It is popular language for managing and accessing content of the relational database. The advantages of using MySQL, it is fast, flexible and quick processing. MySQL is most preferably used with PHP server. It is compatible with platforms including Linux, UNIX and Windows. It is a client-server model. MySQL also provides features like data security.

- Spring ‘REST’ API

  The 'REST' API is utilized to get/send values in a key-esteem pair from/to the server. For the conveyance of information from the server to the devouring assets, API must be created. For this situation, RESTful based APIs for example 'REST' APIs are utilized to get/send values in a key-esteem pair from/to the server. The innovation utilized for creating REST APIs here is Spring MVC as it gives heartiness and security to different system dangers. Spring connectivity to the MySQL Database is done by mysql-connector v8.5 library and for web-services jackson v2.2.3 library is used in creation of REST based APIs.

- Apache Tomcat Server

  It is utilized to convey .war records made utilizing the spring system. It is utilized for sending of RESTful APIs made by Spring MVC in the best possible condition. Organization is as simple as replicating the .war record of our code made utilizing spring structure. Easy Apache (right now v4) is to be introduced on the facilitating gave to you, after which you can transfer your .war record after that unfasten it and you are as great to go.

C. Methods

- 3D Reconstruction

  3D reconstruction is the method in which we capture the shape and appearance of real objects. This process can be achieved using active or passive methods. Active methods provide depth map and it also gives insight about reconstructing the 3D profile by numerical approximation approach and helps in building objects. On the other hand, Passive methods does not tamper the reconstructed object, here there is usage of sensors which helps in measuring the radiance reflected from object's surface to guess its 3D structure using image understanding and processing. To generate 3D models from a chain of images is far cheaper than previous processes like 3D scanner. By using 3D reconstruction algorithm like Structure from Motion (SFM) algorithms and Multi View Stereo (MVS) algorithms we can create a 3D model.[6] Structure from Motion (SFM) is basically used for structuring images which allows estimation of photo location and other camera parameters. In Multi view stereo (MVS) information from SFM are given as an input and it creates a 3D dense point cloud. We have to first use SFM and then MVS for creating a 3D model from set of images.[7] These algorithms are traditional approaches of 3D reconstruction; therefore, we use SLAM algorithm which is most popular for augmented reality. Also, SFM and MVS are static algorithm whereas SLAM is a dynamic one. Depth sensing Algorithm is also used for better accuracy of augmentation. 3D reconstruction can also be done using software like Blender and Maya.

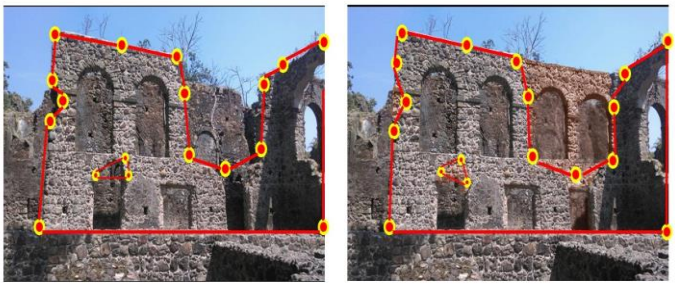

Fig 3. Feature point mapping & Broken Edge Detection

- Photogrammetry Methodology

  Photogrammetry is the process which gathers measurements in the physical world with the help of computer analysis of images captured by camera and is a well-known scientific tool. Photogrammetry is used to capture measurements of fixed points for estimating measurements of the photographed subject which also can be used in 3D. Pictures can be clicked from DSLR cameras form various sides of the buildings. [5] With these images a 3d model is produced after processing it properly. Firstly, we will do configuration of DLSR based on Point of Interest and Capturing criteria. Then photos will be captured using this configuration. Raw images that are captured are then aligned and a dense point cloud will be built. A 3D mesh is created from this cloud and a 3D object geometry is created.

D. Algorithms

- SLAM [8]

  Slam is an acronym for Simultaneous Localization and Mapping. SLAM is used to dynamically map and mark the feature points of the target image. Now the advantage of using SLAM is that it maps unknown spaces and it is drift free. It also is used extensively as it is real time. The architecture of SLAM consists of following components.

  1) Sensor data: They are basically devices like mobiles which includes camera gyroscope and accelerometer. This can be augmented by some sensors like GPS, depth sensor, light sensor etc.

  2) Front end: In this phase feature extraction takes place. This feature points are associated with the 3D position of the target by allocating key points also known as map points.

  3) Back end: Backend phase usually establishes relation between different frames. It also localizes the camera and helps in managing the overall

geometric construction. Algorithms are used to create a 3D dense point cloud.

4) SLAM estimate: This phase shows the result of our algorithm implementation which is tracked features and camera position.

A very good example of SLAM is Orb-SLAM which gives excellent results. Also, SLAM has features like loop detection and loop closing which helps in detecting the target even from different angles of the camera.

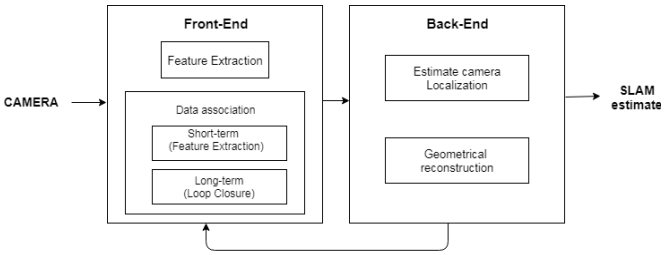

Fig 4. SLAM Architecture

- Fusion

FUSION is an algorithm used by Vuforia engine for augmented reality. Basically, Fusion maps and marks the feature points by using combination of SLAM and ViSLAM. As SLAM is explained earlier let's talk about ViSLAM. ViSLAM is combination of SLAM and Visual-Inertial Odometry. The advantage of using this algorithm is, it works more efficiently then SLAM in low feature environments. It is also providing robustness for track recovery. FUSION also provides Platform Enablers. These enablers help to run application in different environments like Windows, Android or IOS. For Android it uses AR Core, for IOS it uses ARkit and for windows it uses MR. The main features of fusion are as follows

- Device Tracker – It helps in providing six-degree-of-freedom Device Pose.
- Ground Plane – It enables virtual substance to be set on level planes in the earth.
- Extended Tracking – It empowers expanded following for all Vuforia target types.

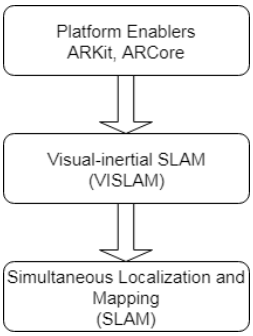

Fig 5. Flow of Fusion Algorithm

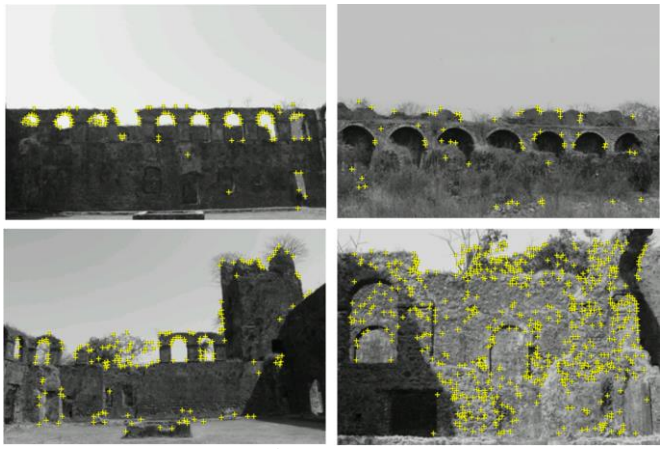

Fig 6. Output of Fusion Algorithm

- Depth Sensing Algorithm [9]

Depth sensing algorithm is used for 3D rendering of image in a very precise manner. In augmented reality it is important that superimposition is done properly so Depth sensing algorithm takes care about it. It is done using following steps.

- Stereo Camera Calibration:

It is done once and it is an offline process. Multiple snapshots of the target structures have to be taken. With the help of this images 2D points are automatically detected and relative 3D points are known and with the help of 2D-3D correspondence proper optimized camera parameters.

- Depth Sensing can be applied by two approaches

1. Single Frame Depth Sensing: In this approach using a single image frame we try to recover the 3D depth of the image. It is used for images having sparse 3D structures. Steps involved are

a) Image Undistortion and rectification –

Here image is first brought to its proper state by compensating non-linear image deformation using some parameters and then it is rectified by some transforms

b) 2D disparity estimation –

It compares the first left pixel using coarse-to-fine block matching algorithm to get right pixel. D=XL- XR

c) 3D depth estimation by triangulation –

In this phase we construct the 3D structure using triangulation method.

$$x_L = \frac{f}{Z}\left(X - \frac{B}{2}\right), x_L - d = \frac{f}{Z}\left(X + \frac{B}{2}\right) \Rightarrow Z = \frac{fB}{d} \Rightarrow X = \frac{Zx_L}{f} + \frac{B}{2}, Y = \frac{Zy}{f}$$

2. Multi-frame Depth Sensing: For better and higher quality of 3D reconstruction we use multiple images here Following steps are considered

a) SFM –

Structure from Motion algorithm is applied on several images of the target object to get 3D rotation and translation. A matrix is created and with the help of that a 3D model is made which are fed into optimization process known as Bundle Adjustment.

b) Multi view stereo reconstruction –

After crating 3D model now, we get into the depth sensing part. We apply Multi view stereo algorithm based on plane sweep on model to recover 3D depth. It evaluates all the pixel's depth and selects the one having highest photo-consistency.

c) Confidence based depth fusion –

The earlier method generated a large amount of redundant data. Now to optimize this we will apply a depth fusion algorithm which fuses information based on multiple view. The 3D point having highest confidence measure will replace small points in local neighborhood. It removes noise and smoothen structure scene.

- Augmented Reality Rendering:

Pixel based maps are created which helps in augmented rendering. Here a depth guided blending algorithm is an applied on two images one having the environment part and other having the virtual object in it. This provides a better realistic view. In final view image will smaller depth i.e. nearer to the camera is superimposed on the image having bigger depth and which is far from camera. This is how depth sensing algorithm is used for Augmented Reality.

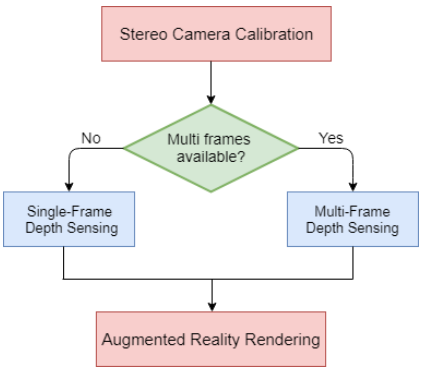

Fig 7. Depth Sensing Algorithm Architecture

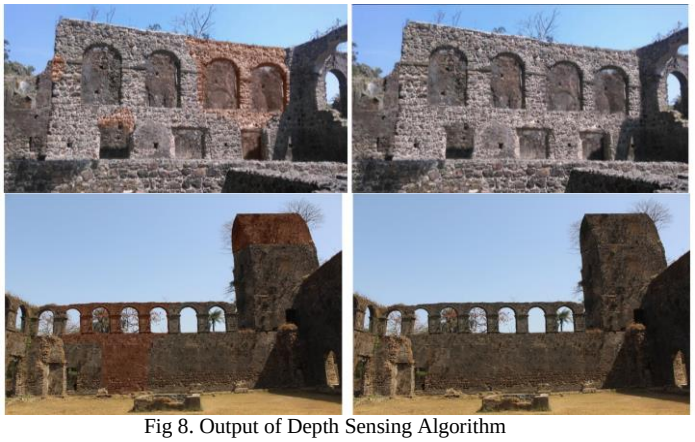

Fig 8. Output of Depth Sensing Algorithm

E. *System Models*

- Use Case

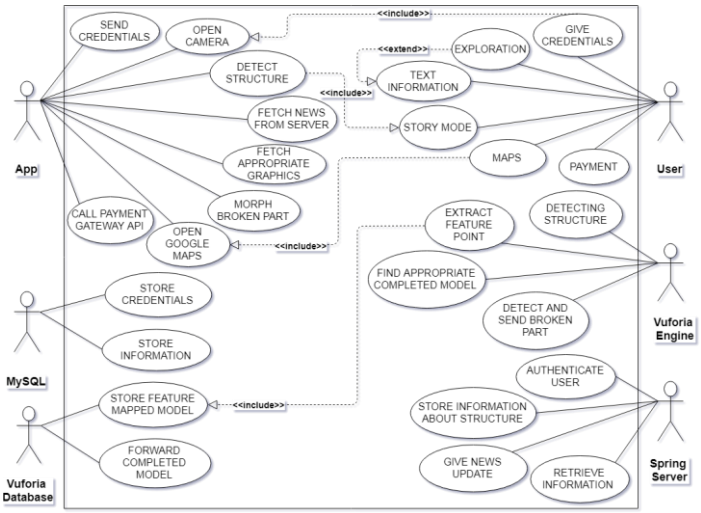

Fig 9. Use Case Diagram

- Activity Diagram

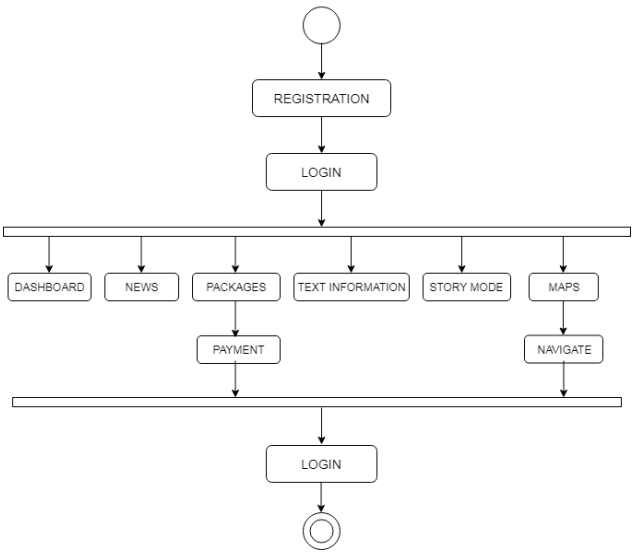

Fig 10. Activity Diagram

IV. Expected Outcome

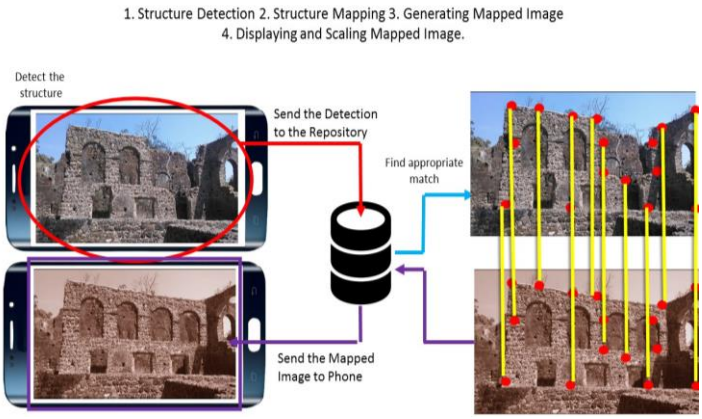

Fig 11. Workflow Diagram

We point our camera of the mobile phone to the deteriorated structure it will detect it and send it to the repository. Then repository will find the appropriate match for the structure and after mapping and scaling it with its ancient picture which is stored in repository it will only send only deteriorated part of the structure which will be morphed on the mobile phone screen. In this way it will display an ancient image at the place of original image.

As seen above the initially seen image is replaced by a completed version. The look and feel have been attempted to keep as real as possible without any disruption between the movement of the frame hence keeping the visual pleasure intact.

A. *Story Mode*

On clicking the dashboard, we switch to Vuforia application where story mode button is provided. Story mode is more attractive feature of the application which shows graphics related to that monument if any. This feature is available with graphical, textual and visual format which gives additional information regarding history of that particular site. Graphics will be displayed on the screen when particular structure related to that monument will be detected by pointing our camera. Also, if we remove camera pointing towards the structure, the story mode will be disabled.

B. *Slider*

While pointing the camera towards the deteriorated structure we can also view more information about the particular site on slider. It will be consisting of images and important stories of that monument.

C. *Map*

One more supplementary feature is provided which shows the current position of user. This map also shows the structures which are completed for that monument, helping us as an offline map. More functionality is given to know the current location of ourselves. By clicking on Navigate button user will be redirected to his/her current location using google API.

Fig 12. Final Outcome – Vasai Fort

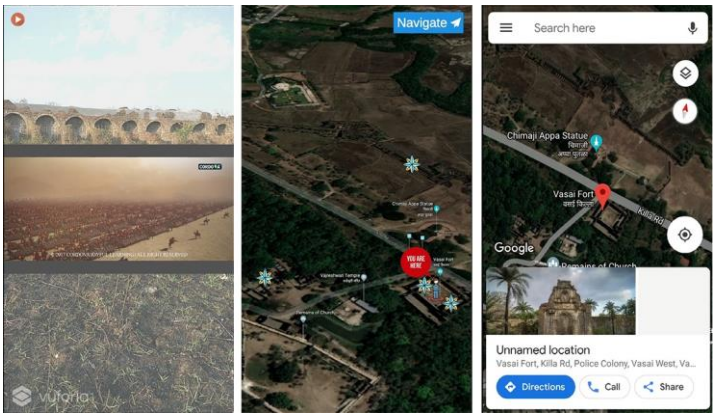

Fig 13. Story Mode & Maps

V. EXPERRIMENTAL RESULTS

The experimental results are expected to be as follows:

- The number of tourists increasing.
- The harassment by the local guides done to tourist and the general audience reducing over the time.
- Income due to tourism increasing.
- The local businesses flourishing.
- The immersive nature of the system rejuvenates the mind and soul of the user.

CONCLUSION

Result will be increment in number of audiences at the historical sites and monuments as the system will create a never-ending hunger for knowledge and inquisitiveness. Interest will spark in the minds of youth to learn more about the culture and traditions of the local surrounding hence beneficial to keep the majority of the audience close to our roots. Educational field will also get benefited by this technology as they can have their field trips in these completed monuments and additional information in the form of textual as well as audio format can be provided for them.

For future advancement, we will be adding few more functionalities. We will try to replicate the full 3D affect through augmentation. Suppose, there was a door so you will get a virtual 3D door in front of you and you can enter into it experiencing the actual scenario of the monument. Similarly, if roof is not present then by pointing your camera towards targeted image will complete the roof with its actual color giving a real-time replica of the previous beauty and at the same time interacting with you.

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