

# APPLICATION OF AUGMENTED REALITY FOR VIRTUAL RECONSTRUCTION AND RESTORATION OF ARCHAEOLOGICAL ARTIFACTS

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**Abstract—** This article demonstrates integrating augmented reality applications, 3D models, and photogrammetric reformation that enables visualizing stone sculptures even though they are heavily ruined or fragmented. Firstly, our research focuses on recreating the original appearance of the broken statue as a 3D model by using standard-resolution photos to carry out the photogrammetry using software (free software if possible). We then use other 3D models of similar sculptures from the same time (made using photogrammetry) or prepare 3D models of missing parts of the base sculpture based on the records of ancient archaeological research. Secondly, the research involves building a custom Android app that can instantly augment the missing parts of the damaged statue with the help of the 3D model we built. As a case study, we used sculptures at the Venkatappa Art Gallery in Bengaluru. Finally, the reconstructed statue is viewed using an AR App that overlays the reconstructed missing portion of the damaged statue virtually.

**Keywords—** Cultural Heritage, Virtual Reconstruction, Augmented Reality, Photogrammetry, Real-time visualization.

## I. INTRODUCTION

Digital technology helps a range of fields in cultural heritage like rebuilding, tracking, estimation, digitization, and visualization. 3D models are used to study the structures, measurements, stability, and their changes over the years, etc. [1]. In the realm of measurement technology, the acquisition of information which was previously challenging and potentially hazardous has been revolutionized. The utilization of a digital camera paired with readily available software now enables the efficient collection and processing of information that was once considered arduous. Presently, digital close-range photogrammetry emerges as a cost-effective solution, making it feasible to model diverse structures with enhanced efficiency and budget-friendly considerations [2]. Digital models are reconstructed via photogrammetric applications through the images collected on the web, especially in instances where the artifacts are significantly damaged or lost artifacts when we focus on reconstructing the original appearances [3,4]. In [5] the field of conserving and restoring carved elements, digital technologies have undergone rigorous testing. This collaborative approach enhances understanding of their methodologies. Photogrammetric techniques play a pivotal role, supported by advancements in hardware and software. The use of improved tools, including open source validated in this context [6]. The focus is on the accuracy of the result. The result must be globally positive in the 3D scene even with the presence of texture-deficient or reflective surfaces. Technologies such as Augmented Reality, 3D printing, and 3D scanning are used to represent the complexity of a historical site and its heritage [7]. A few museums and archaeological sites already use digital tools for the conservation of the sites and the artifacts, but providing an interactive and immersive experience for tourists is very limited. Photogrammetry is increasingly used to model complex figures and it is an alternative to the current trend of 3d scans as it is flexible and is low-cost [8]. This paper focuses on using photogrammetric 3d Reconstruction and the use of AR to increase the interaction of the artifact. As a trial of this process, we focus on a sculpture from Venkatappa Art Gallery, Bengaluru, which lacks both hands. By modelling and merging the ruined sculpture with the missing parts which are created through the process of 3d modelling and photogrammetry, the actual look of the sculpture can be shown. The reconstructed sculpture can be seen with the help of an augmented reality app that overlays the virtually rebuilt parts onto the damaged sculpture.

## II. METHODOLOGY

### A. Overview

The first part of this project is to digitally reconstruct the damaged statue and the missing parts using photogrammetry and other 3D modelling techniques using the software (free software if possible). Further, we restore the appearance of the statue by integrating the missing parts and the statue to obtain the complete appearance of the Statue.

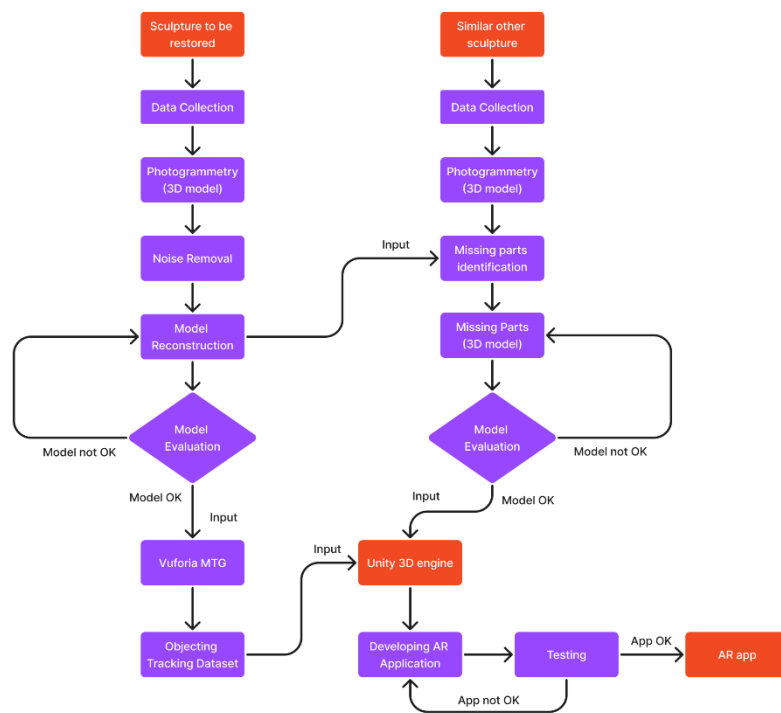


Fig. 1. Project Workflow

The basic steps of our project workflow are as follows:

- Virtually rebuilding the ruined sculpture and its missing parts from similar other sculptures using Photogrammetry.
- Making some changes to these missing parts, if needed, by slightly re-modelling them and adding them to our primary model.
- Our original sculpture is finally “augmented” with the missing parts; a dedicated AR application is developed to visualize these results on an Android mobile phone.

## B. Data collection



Fig. 2. Deformed Sculpture



Fig. 3. Reference Sculpture

The initial phase of the research focuses on reconstructing the original appearance of the damaged sculpture. To achieve this, photogrammetric techniques are employed, utilizing standard-resolution photos. We aim to create a 3D model, and whenever possible, we opt for free software. In the data collection process, we captured 308 photos of the damaged sculpture, and 536 photos of the reference sculpture using the IQOO 7 camera with specifications: 48 MP (f/1.8, 26mm (wide), 1/2.0", 0.8 $\mu$ m, PDAF, OIS). These photos are illustrated in Fig. 2 and Fig. 3.

### C. Photogrammetry

“Analysing multiple photographs of an object or environment to construct precise 3D models. It involves identifying common points in the images to extract geometric information.”

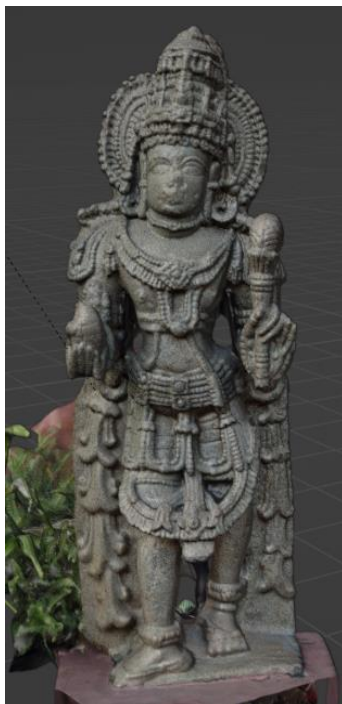


Fig. 4. Reconstructed 3D model of the Deformed Sculpture



Fig. 5. Reconstructed 3D model of the Reference Sculpture

Following the data collection, we performed photogrammetric reconstruction using the free software ‘Meshroom’, but the results were not satisfactory. Then we used free software for the MacBook (M series) named ‘PhotoCatch’ which gave good results and was very accurate. We used 308 images of the damaged sculpture taken from different angles, to generate a 3D model of it, as depicted in (Fig. 4). Similarly, we also built a 3D model with 536 images of a similar reference sculpture to get the missing parts for our original damaged sculpture (Fig. 5).



#### D. Noise Removal and Reconstruction



Fig. 6. 3D model of the original deformed structure after noise removal



Fig. 7. 3D model of the missing parts from the reference structure

The model is generated through the software PhotoCatch. It is a free-to-use app in macOS for making photogrammetric models. The process involves taking multiple pictures of the target which is fed into the PhotoCatch app. PhotoCatch then takes the images and performs a series of operations to create a 3D model of the target. The target taken for our study is a damaged sculpture from the Venkatappa Art Gallery, Bengaluru. Multiple images of the sculpture were taken from multiple angles in the same environment. These are then imported into PhotoCatch. PhotoCatch analyses these images and starts the process of reconstructing the real-world object (in this case the sculpture). The output model generated contains noise and unwanted extensions and meshes in the output model. This noise is usually the background information that is also reconstructed into the output model and some other unwanted features are also reconstructed into the model. To remove the noise generated from the photogrammetric process and to edit and preprocess the model we use the free software Blender (open source). Blender is an open software that is primarily used for working with 3D models, like making 3D models, editing, sculpting, etc. It is one of the most widely used software for working with 3D models. Blender is used to remove the noise from the generated 3D model of the damaged sculpture. Subtractive sculpting is used to remove the unnecessary features of the model. The model is also scaled and positioned within the Blender app. The output is then exported as a '.obj' format file. This will be used later in the model target generation phase which is used as the target for object tracking and in augmenting the missing parts of the object AR application creation phase. Additionally, a similar process is performed on the reference sculpture from the Venkatappa art gallery as well to get the missing parts for the original sculpture. A similar photogrammetric process is applied to the reference sculpture using PhotoCatch and the noise removal and scaling are followed to extract the missing parts in blender.

#### E. Restoration and AR Application

An AR application is used to visualize the virtual restoration of the damaged sculpture. The application is built in the Unity3D engine. The Vuforia Plugin package has been used for the implementation of the Augmented Reality mobile application. Object tracking from Vuforia is taken as the mechanism to restore the missing parts.



Fig. 8a, 8b. Original Sculpture after Virtual Restoration

The implementation and the process of building the AR Application are as follows:

- The photogrammetrically reconstructed 3D model of the damaged sculpture i.e., the '.obj' file exported after the noise removal process in the Blender software (open source) is imported into the Model Target Generator (MTG), a software from Vuforia.
- The dataset that is needed to track the object (damaged sculpture) for the object tracking process is generated by the Model Target Generator (MTG) using guide views. There are many guide views in Model Target Generator (MTG). 'Full 360° guide view' which takes many hours of training can be used for more precise results, but here we used a simple '2D guide view' for the object Tracking process. This dataset is exported for use in the Unity3D engine.
- The Vuforia Plugin package is imported into the Unity3D engine.
- The environment is set in Unity with the addition of an AR camera and a model target object from Vuforia.
- The '.unitypackage' file from the generated 3D model dataset created by Model Target Generator (MTG) is imported into the Unity3D engine.
- We choose the imported model target for the Unity 3D engine and the missing parts are scaled and placed in the appropriate places with the right dimensions regarding the model target (Fig. 8a, 8b).
- After all these processes we build the '.apk' file (i.e., executable file for Android) via Unity3D engine for visualizing the virtually restored missing parts of the damaged object i.e., the damaged sculpture in real-time using the mobile camera through the mobile application.
- The ARKit plugin package can be used as an alternative to Vuforia for object tracking, ARKit is used for developing applications for iOS devices.

### III. RESULTS



Fig. 9a, 9b. Expected Output

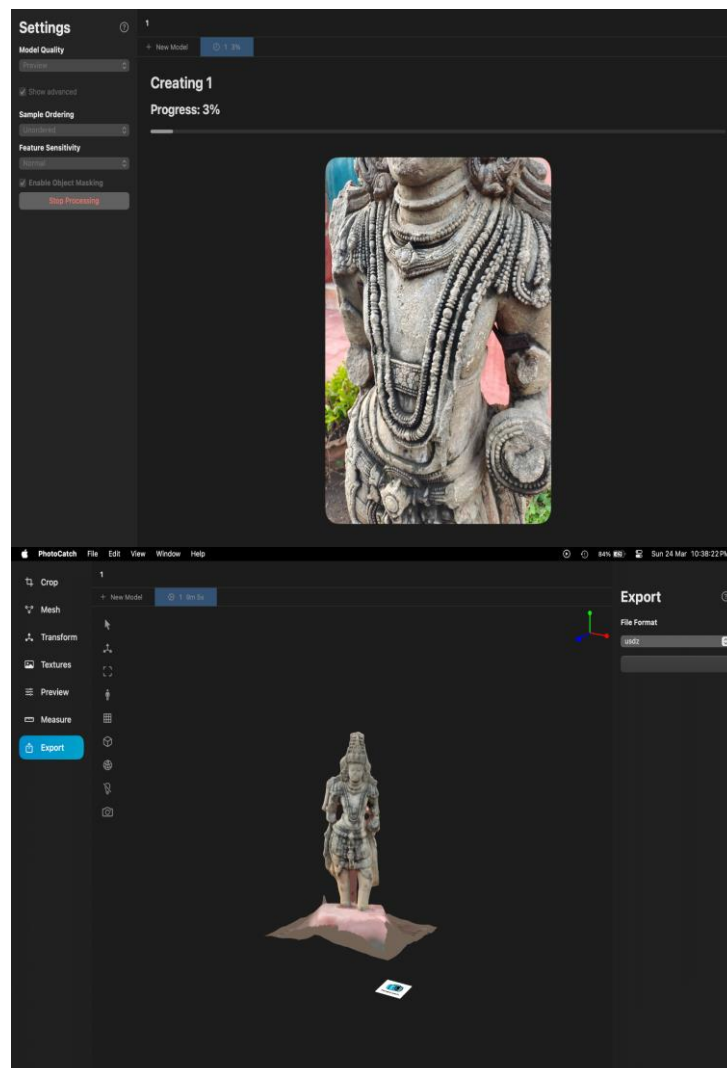


Fig 10a, 10b. Output of PhotoCatch software (Model Reconstruction)

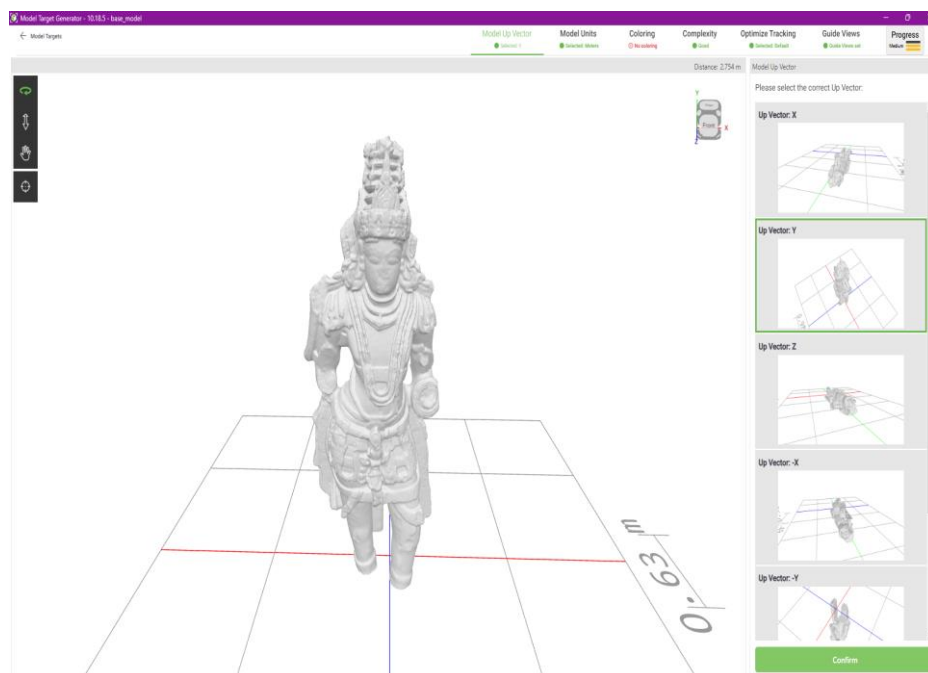


Fig 11. VUFORIA Output for Model tracking

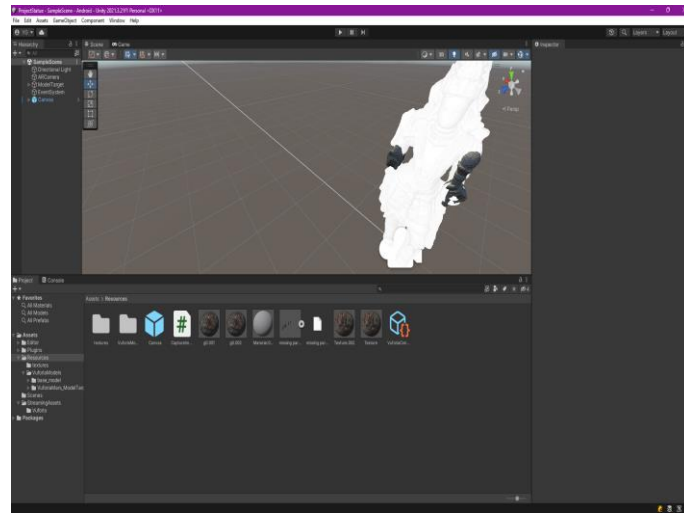


Fig. 12. Preparing object tracking in Unity3D with MTG dataset



Fig. 13a, 13b. Obtained Output

The Augmented reality (AR) application can dynamically render the missing parts of the damaged sculpture by superimposing them onto the damaged statue in the actual environment (Fig. 10a, 10b). This process results in the creation of a 3D representation of the virtually rebuilt sculpture digitally, which users can visualize and interact with via a mobile AR application.

#### IV. CONCLUSION

This Study introduces an approach to reconstruct and restore the missing segments of the stone sculpture by utilizing 3D modeling techniques photogrammetry and augmented reality. The initial step involves reconstructing the broken statue for object tracking and reconstructing the missing parts from the other sculpture related to the damaged sculpture which is from the same period and has the same history. The reconstructed missing parts must align with the rest of the sculpture in terms of stone surface finishing, color, texture, and overall finishing. The selection of missing parts involves studying other archaeological models with similar characteristics. Photogrammetry's effectiveness depends on factors like lighting conditions which demand post-processing of images for improved results.

This technique can provide a tool for the reconstruction and restoration of lost heritage sites, sculptures, etc. Through augmented reality, users can have better visualization.

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