

Restoration of World Famous 2200-Year-Old Paintings with AI: Digital Heritage of Ajanta Caves

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Abstract—Digital heritage, encompassing the preservation and promotion of cultural artifacts, traditions, and identities in the digital realm, has emerged as a critical field in the era of technology and globalization. As societies increasingly embrace digital platforms, it becomes imperative to explore the potential and challenges of documenting, safeguarding, and providing access to our collective heritage. Artificial Intelligence is another useful tool for preventing cultural heritage. AI-powered image processing can have a profound impact on preserving and interpreting cultural artifacts, historical documents, and artwork. By harnessing the power of AI, heritage professionals can enhance the preservation and restoration process by accurately analyzing images to detect damage or deterioration in delicate artifacts. In this proposed research work we are trying to digitally preserve and restore the murals recovered from cultural heritage sites. In this paper we have used OpenCV in Python to restore historical paintings. For this study most famous paintings of Ajanta Caves 1 are selected. In this paper we have demonstrated the restoration of damaged image of Bodhisattva Padmapani from cave 1 at Ajanta monastery. We have used methods like Denoising, Gray Scaling, Thresholding, Dilation etc.

Index Terms— Digital Heritage, Artificial Intelligence, Image Processing, Python, OpenCV, Restoration

I. INTRODUCTION

The Ajanta caves, The Ajanta Caves, renowned as a UNESCO World Heritage site located in Maharashtra, India, are unquestionably revered as magnificent expressions of Buddhist religious art. These masterpieces have rightfully earned a universal recognition for their exceptional beauty and significance. Carved into the rock face of a horseshoe-shaped cliff, these ancient caves were painstakingly created by skilled artisans between the 2nd century BCE and 5th century CE. Inside these caves, visitors are treated to an enchanting display of frescoes, paintings, and sculptures that depict various episodes from the life of Gautam Buddha. It is need of time to digitize and preserve our Ajanta caves heritage for our future generations to know about our culture and understand it.

The Ajanta Caves are an awe-inspiring collection of approximately 30 rock-cut Buddhist cave monuments. The caves are numbered not chronologically but as a matter of convenience, starting with the one at the outmost extremity. Cave 1 is one of the finest monasteries at Ajanta, distinguished from other.

The Ajanta Cave painting techniques are a testament to the exquisite artistry and mastery of the ancient Indian artists. One of the notable aspects of these paintings is their unparalleled level of detail and precision. The artists employed a meticulous technique called tempera, where they mixed pigments intimately with a binding agent such as glue or egg yolk to create vibrant colors that still retain their vividness today. The paintings also exhibit a high level of naturalism, achieved through careful observation and an understanding of shades, contours, and proportions. In addition to their technical excellence, the artists demonstrated remarkable skill in storytelling, using narrative devices such

as color symbolism and juxtaposition to convey emotions and themes effectively. These cave paintings continue to captivate viewers with their timeless beauty while providing invaluable insights into ancient Indian culture and artistic traditions.

Ajanta Cave 1 is an archeological masterpiece, renowned for its unique depiction of Jataka Tales on the walls. These tales, originating from Buddhist literature, narrate the previous lives of the Buddha in various forms, illustrating moral lessons and virtues. The paintings within Cave 1 are a visual representation of these moral stories, captivating viewers with their intricate detailing and rich symbolism. Also, painting of Bodhisattvas and Buddha on walls. The animal figures depicted on these ceilings are infused with lifelike details and expressive poses, capturing the essence of each creature. There are lot of geometrical designs on ceilings in the caves. Bodhisattva Padmapani and Bodhisattva Vajrapani painted on wall. So, Cave 1 is selected for study.

In this paper we have demonstrated the restoration of world's most famous 2200-year-old painting of Bodhisattva Padmapani from cave 1 at Ajanta monastery has demonstrated. Bodhisattva Padmapani at Ajanta Caves no 1 is a remarkable masterpiece of ancient Indian art and a significant representation of Buddhist iconography.

The Charter on the Preservation of Digital Heritage, developed by UNESCO, offers a comprehensive definition of digital heritage and underscores its significance in our increasingly digital world. According to this charter, digital heritage encompasses all forms of digitally stored information and knowledge that have cultural, historical, scientific, or educational value. It includes not only electronic documents but also websites, databases, software applications, multimedia content, and virtual representations

of physical artifacts or places. The charter emphasizes that the preservation and accessibility of digital heritage are essential for maintaining cultural diversity and promoting intercultural dialogue. Furthermore, it stresses the need for active collaboration between governments, institutions, professionals, communities, and individuals in order to safeguard these valuable digital resources from technical obsolescence or loss due to human error or malicious intent. The Charter on the Preservation of Digital Heritage serves as a vital framework for guiding policies and practices aimed at preserving our global digital legacy for future generations.

The purpose of digital heritage is to preserve, document, and provide universal access to cultural, historical, and scientific artifacts in a digital format. In today's rapidly advancing technological era, where physical objects are prone to degradation or loss, digitizing heritage has become an essential practice. By doing so, we ensure that future generations can explore and study our shared history regardless of geographical boundaries or time constraints. Additionally, digital preservation allows for the conservation of fragile materials such as ancient manuscripts or delicate artworks by minimizing physical handling. It also enables the dissemination of knowledge on a global scale through online platforms and interactive exhibits. Furthermore, digital heritage facilitates research and collaboration among scholars worldwide by providing them with easily accessible resources for analysis and interpretation.

The main field in which AI is implemented and has garnered significant attention in recent years is image restoration. With the ever-increasing amount of digital content produced and shared globally, the need for enhancing and restoring images has become crucial. Artificial Intelligence algorithms have revolutionized this process by automating and significantly expediting tasks that required immense time and effort from human experts. Image restoration using AI involves removing various types of unwanted imperfections such as scratches, noise, blurriness, or color degradation from images while preserving their original structure and context. This is achieved through sophisticated machine learning techniques which involve training large neural networks on extensive datasets of both degraded and high-quality images. Image processing techniques helps digital restoration but it does not alter originality of the masterpieces.

II. DIGITAL HERITAGE ON AJNATA CAVES

Nashik-based artist-photographer Prasad Pawar, who has been documenting, photographing, and digitally restoring the Buddhist paintings and sculptures in Ajanta for 27 years, but without touching them. The artists could not have used mashaals because they would suck the oxygen out of the room, making it difficult to work, and leave carbon deposits on the artwork.

Today technological tools like AI and automation help make the restoration process easier and more efficient. The

Tech4Heritage hackathon was conducted to digitally preserve and restore the murals recovered from these heritage sites. One team comprised Arjav Jain and Aryan Prasad (all second-year students of B.Tech. Mechanical Engineering at IIT Roorkee). They have started with damaged images from the Ajanta caves, which they downloaded from the Internet, to build a unique dataset of images. This served as a foundation upon which a generative model was trained to identify the damaged areas. These images were later restored, through AI models utilizing Generative Adversarial Networks (GANs).

After reviewing some of the work on digital heritage and cultural computing, it is observed that some work is done on Ajanta Caves using digital heritage but there is no work on Ajanta Caves using the concept of cultural computing. So, we are trying address this gap in our proposed research work.

III. PROPOSED SYSTEM

This section describes image restoration process performed with AI programming with Python. The images restoration process performed with AI programming using Python is a powerful and effective technique that leverages the capabilities of artificial intelligence to enhance and restore damaged or low-quality images. Through the use of advanced algorithms, machine learning models are trained on vast datasets to learn patterns, textures, and structures in images, enabling them to intelligently recognize and correct various types of distortions such as blur, noise, compression artifacts, and color fading. This process typically involves several steps including image denoising, deblurring, super-resolution, and color correction. Leveraging deep neural networks and convolutional neural networks (CNNs), AI-powered image restoration methods can analyze the features of an image at different levels of abstraction and make accurate predictions about missing or degraded information. The seamless integration of AI programming with Python facilitates the implementation and customization of these techniques by providing a comprehensive ecosystem for data preprocessing, model training, validation, and inference. As a result, the image restoration process performed with AI programming in Python has revolutionized the field of digital imaging by enabling professionals to effectively salvage compromised visual content with exceptional accuracy and fidelity.

OpenCV (Open-Source Computer Vision Library) is a powerful and widely-used computer vision library that offers an extensive collection of algorithms and tools for image and video analysis. It provides developers with a comprehensive set of functions to process, manipulate, and analyze visual data, making it an essential tool for various applications in fields such as robotics, augmented reality, surveillance systems, and machine learning. OpenCV supports multiple programming languages including C++, Python, Java, and MATLAB, allowing developers to choose their preferred language for implementation. The library incorporates cutting-edge techniques in computer vision such as feature

extraction, object detection, and image stitching. Its high-performance capabilities ensure efficient processing of real-time video streams and large image datasets. With its rich set of functionalities and wide community support, OpenCV serves as a valuable resource for professionals seeking robust solutions in the field of computer vision.

A. Methodology

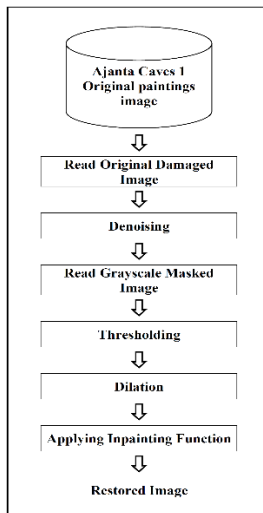


Fig.1. Proposed System Architecture

The proposed system is based on primary and secondary data. Primary data will be collected directly from Ajanta Cave Cultures and secondary data is collected from books, websites etc. Real contents and objects of Ajanta caves will be collected from primary and secondary data sources. After data collection, data processing, digitization will be done.

B. Image Restoration in Python

Initially the path of the original Bodhisattva Padmapani damaged image file is mentioned and is loaded in our program.

Code:

```
OriginalImage=cv2.imread("Padmapani.jpg")
cv2.imshow("Original Image",OriginalImage)
```

Result:



Fig.2. Original Damaged Image of Bodhisattva Padmapani.

First step is Denoising damaged image. In order to restore a damaged image, one effective method is to denoise it using the Fast Means Denoising (FMD) technique. FMD is a powerful algorithm that aims to eliminate unwanted noise while preserving important details within an image. This process involves analyzing the pixel values of neighboring pixels and calculating an average value based on those observations. By iteratively applying this averaging process across the entire image, FMD effectively reduces noise without losing crucial information. This method is particularly useful in scenarios where images may have been distorted due to factors such as sensor limitations or compression artifacts. With its ability to suppress noise and enhance image quality, FMD provides professionals with a valuable tool for refining damaged images in various industries such as photography, medical imaging, or surveillance.

Code:

```
dst = cv2.fastNlMeansDenoisingColored(OriginalImage,None,10,10,7,21)
cv2.imshow("Denoised Image",dst)
```

Result:



Fig.3. Denoised Image

In the next step, the creation of a greyscale masked image based on the areas requiring correction. This procedure involves identifying specific regions within a damaged image that necessitate repair and marking them accordingly. By creating this masked image, professionals obtain a detailed visual representation solely showcasing the problematic areas, which can be paramount for subsequent restoration processes. The greyscale format aids in isolating and emphasizing the damaged portions, facilitating targeted interventions to rectify issues such as scratches, blemishes, or other imperfections. This highly refined approach enables technicians to focus their expertise exclusively on these marked regions while avoiding any unnecessary alterations to intact parts of the image. As a result, greyscale masked images provide an invaluable tool for efficiently restoring damaged visuals with precision and accuracy.

Code:

```
markedDamges=cv2.imread("markedImage.jpg",0)
cv2.imshow(" Grayscale Masked Image",markedDamges)
```

Result:



Fig.4. Grayscale Marked Image

Next, transforming this masked grayscale image file into a binary image through thresholding. This method allows for better visualization and analysis of specific objects within the image. Thresholding involves setting a pixel value limit, above which pixels are classified as foreground or object pixels, while below that limit, they are considered background pixels. By converting the grayscale image into a binary format, it becomes easier to segment and isolate specific objects or regions of interest from complex backgrounds. Furthermore, this conversion simplifies subsequent processing steps such as feature extraction or object recognition algorithms, enabling more accurate and efficient analyses. The use of thresholding and converting grayscale images into binary images represents an important step in improving image restoration techniques and has numerous applications within industries like medical imaging, surveillance systems, and computer vision research.

Code:

```
ret, thresh=cv2.threshold(markedDamages,254,255,cv2.THRESH_BINARY)
cv2.imshow("Marked Threshold",thresh)
```

Result:



Fig.5. Marked Threshold

Dilation is an essential operation within image processing techniques when dealing with thresholded images due to the reduction of thickness in marked areas caused by thresholding. Thresholding, a commonly used technique to

segment objects from an image, assigns a binary value to each pixel based on a selected threshold value. However, this method often leads to incomplete object detection and thinning of regions of interest. Dilation enables us to counteract these limitations by expanding the boundaries of the marked regions, thereby enhancing their overall shape and increasing their visual prominence for subsequent analysis or application-dependent tasks. By iteratively applying dilation operations on the thresholded image, we can bridge gaps and fill in narrow regions between detected objects. This process ultimately ensures greater accuracy in object identification and preserves relevant structural details while mitigating potential inaccuracies or omissions introduced during thresholding. Consequently, dilation plays a crucial role in compensating for the inherent shortcomings of thresholding and is an indispensable step towards obtaining more accurate results in various image processing applications.

Code:

```
kernel=np.ones((7,7),np.uint8)
mask=cv2.dilate(thresh,kernel,iterations=1)
cv2.imshow("Masked Image",mask)
```

Result:



Fig.6. Masked Image

Final stage is applying Image inpainting, an advanced image processing technique that involves the restoration of damaged or missing parts in an image. The Image Inpainting function, specifically the Fast-Marching Method developed by TELEA, stands out as an efficient and reliable solution for repairing damaged areas. This method utilizes a level set approach combined with a fast-marching algorithm to restore damaged pixels accurately and quickly in an image. By analyzing the surrounding information and context, it is capable of intelligently filling in the missing information to seamlessly blend with the existing content. This state-of-the-art method excels at resolving various inpainting challenges including removing unwanted objects, fixing scratches, restoring old photographs, and repairing digital artifacts. The Image Inpainting function by TELEA proves indispensable within professional settings where quality and efficiency are paramount, such as photo editing studios, forensic investigations, or digital restoration projects.

Code:

```
restoredImage=cv2.inpaint(OriginalImage,mask,3,cv2.INPAINT_TELEA)
cv2.imshow("Restored Image",restoredImage)
```

Result:



Fig.7 Restored Image

IV. CONCLUSIONS

In this paper we have discussed architecture of proposed system for image restoration. We have demonstrated restoration of damaged image of Bodhisattva Padmapani from cave 1 at Ajanta monastery. With the help of Python's OpenCV library, we can leverage the inpainting function to seamlessly restore images by intelligently replacing unwanted elements or reconstructing missing parts. By utilizing advanced algorithms and techniques, OpenCV provides a robust solution for image restoration tasks. Also, image restoration methods like Denoising, Gray Scaling, Thresholding, Dilation are demonstrated with code and its result. In this proposed research work we are successful to digitally preserve and restore the murals recovered from cultural heritage sites.

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