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# Digital Heritage Reconstruction Using Super-resolution and Inpainting

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IMAGING #26*

## ABSTRACT

Heritage sites across the world have witnessed a number of natural calamities, sabotage and damage from visitors, resulting in their present ruined condition. Many sites are now restricted to reduce the risk of further damage. Yet these masterpieces are significant cultural icons and critical markers of past civilizations that future generations need to see. A digitally reconstructed heritage site could diminish further harm by using immersive navigation or walkthrough systems for virtual environments. An exciting key element for the viewer is observing fine details of the historic work and viewing monuments in their undamaged form. This book presents image super-resolution methods and techniques for automatically detecting and inpainting damaged regions in heritage monuments, in order to provide an enhanced visual experience.

The book presents techniques to obtain higher resolution photographs of the digitally reconstructed monuments, and the resulting images can serve as input to immersive walkthrough systems. It begins with the discussion of two novel techniques for image super-resolution and an approach for inpainting a user-supplied region in the given image, followed by a technique to simultaneously perform super-resolution and inpainting of given missing regions. It then introduces a method for automatically detecting and repairing the damage to dominant facial regions in statues, followed by a few approaches for automatic crack repair in images of heritage scenes. This book is a giant step toward ensuring that the iconic sites of our past are always available, and will never be truly lost.

## KEYWORDS

super-resolution, inpainting, cultural heritage, crack detection, digital reconstruction

*To*

*My mother Suniti and my father Gajanan*  
— *MGP*

*Smita, Nidhi and Ninad*  
— *MVJ*

*My mother Niharika, My father Lalit,*  
*My brother Prerak, and Bajararu*  
— *NLK*



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# Preface

Over the past few years, we have witnessed an active participation of many global organizations toward the preservation of cultural heritage. Research in this area is being disseminated through a series of articles in journals, conferences and workshops that focus on the preservation and digital reconstruction of historic monuments. The tools and techniques developed by the vision and graphics community are finding wider applications in this area. Moreover, new techniques are being tailored for the applications involving cultural heritage. This is a sign that initiatives in this area are receiving a greater acceptance among researchers.

With the availability of better facilities for computing, storage and communication systems, we notice that there is a gradual transition toward the development of immersive walkthrough systems and virtual museums. In immersive walkthrough systems, tourists can experience being at a heritage site without physically visiting the site. They can feel an exciting onsite experience with mixed reality by using their handheld devices, with which they can peek into the historic view of the heritage sites. The tourists may be provided a digitally reconstructed view, allowing them to view damaged monuments in their entirety, complete with the skillful work that may have existed prior to any destruction. This possibility drives us toward research in the areas of super-resolution and automatic inpainting for digital heritage reconstruction.

The existing literature and reference books on the topic of digitalization for cultural heritage focus on providing information about the required hardware and software setup, acquisition of images for 2D and 3D rendering, preservation of original objects at the heritage site or in museums as well as creating their imaged replica in digital form, etc. However, the other aspect of digitizing the cultural heritage viz. reconstruction and recovery of details in the lost or deteriorated regions in the photographs of the monuments has received less attention, and the amount of published literature under this category is very much limited.

In this book we discuss this aspect of digitizing the cultural heritage and present methods for image super-resolution and techniques for automatically detecting and inpainting regions like cracks and other damaged regions in heritage monuments. The purpose here is to obtain higher spatial resolution photographs of the repaired monuments, where the repair is performed by automatic detection. The resulting images and videos can then serve as an input for 3D surface estimation and eventually for creating immersive walkthrough systems, justifying the title of this book.

The book is addressed to an audience including, but not limited to, practitioners and researchers having interest in digital heritage reconstruction from a computer vision point of view. The content of this book aims to foster new research ideas in this area. All the works discussed in this book have been covered with sufficient detail and we have also illustrated these with a large

number of figures for better understanding. These works are a part of the project *Indian Digital Heritage (IDH) – Hampi* sponsored by the Department of Science and Technology (DST), Govt. of India (Grant No: NRDMS/11/1586/2009/Phase-II) for which Manjunath V. Joshi has been the principal investigator. Under his supervision, the work for Chapters 2–3 was carried out by Nilay L. Khatri while working as a junior research fellow in the IDH – Hampi project at DA-IICT. The work for Chapters 4–9 has been carried out by Milind G. Padalkar as a part of his Ph.D. thesis.

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