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Digital Heritage: Digital Restoration of ancient paintings

Deepti Vadicherla[1], Vijay B. Gadicha[2]

[1]*Computer Science and Engg, GHRU, Amravati, Maharashtra, India*

[2]*Computer Science and Engg, GHRU, Amravati, Maharashtra, India*

ABSTRACT:

Every country has its own culture and heritage. Ancient paintings have been a very precious treasure in every heritage which helps mankind to understand roots of that culture. But like most ancient artworks it also has structure damage problems like cracks and flakes. In this paper we have discussed digital restoration of ancient paintings. A general framework is discussed which includes stages like damage detection and inpainting process for restoring the damaged paintings. Various types of methods at every stage are discussed with the help of different research done in the field of machine learning. Moreover, we also provide discussion on the future research topics about image inpainting with the help of deep learning algorithms along with the training dataset.

Keywords: *Crack detection, Digital restoration, Inpainting method, Patch based damage detection, Top-hat transform*

I. INTRODUCTION:

India is one of the oldest civilizations in the world with a kaleidoscopic variety and rich cultural heritage. Indian art, like all traditional arts, dedicated to communicate with its religion and philosophy which is in the form of paintings, sculptures and architecture. The traditional painting art forms of India are Tanjore painting, Ajanta paintings, Kerala murals, Miniatures. But because of light exposure, weather conditions and improper handling most ancient artworks get structural damage problems like cracks and flakes. Conventional restoration techniques has its own limitations. Digital restoration of paintings can provide visual estimation of their original appearances, which can help to imagine how the original undamaged work may have looked at the time of creation.

This paper focuses on the digital restoration of damaged paintings in the form of cracks and flakes, where some regions in paintings are missing. Flaking is one of the most common damage problems in ancient paintings[1]. Flaking problem can be divided into two categories, paint layer flaking and earth layer flaking. Age related or mechanical flakes can lead to a missing area in one or more layers of the painting and thus affect the entire paint layer structure. Cracks are very thin and hairline shaped damage. The solution of digital restoration for ancient paintings either assume the damage region has known or focus on small cracks detection and inpainting. The basic method of digital restoration of images is as shown in Fig. 1.

The cracks can be detected by thresholding the output of the morphological top-hat transform. The cracks are classified using an unsupervised approach, which incorporates fuzzy clustering of the patterns [2]. In [3], the authors proposed a framework with three new detection methods which are combined in order to detect cracks of

different sizes. For the subsequent inpainting stage, a patch-based technique is applied to handle the noisy nature of the images and to increase the performance in the crack removal. A framework is proposed for flakes detection and inpainting of ancient Chinese paintings via the nearest neighboring method [3]. A virtual restoration of ancient Chinese paintings via colour contrast enhancement and lacuna texture synthesis was proposed in [2]. The flacks considered here are irregular hole patterns and randomly distributed in an image.

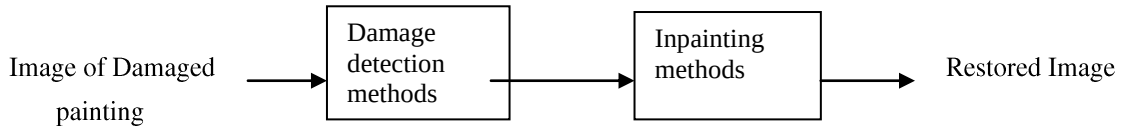

Fig. 1. Steps of digital restoration of damaged Image.

The remainder of this paper is organized as follows: In Section II, we present a review of crack and patch based damage detection frameworks. Then, in Section III, review of inpainting frameworks for digital restoration of damaged paintings are discussed followed by conclusion in Section IV.

II. DAMAGE DETECTION

In this section the study of research papers regarding damage detection is discussed. Here damage detection is in terms of crack and missing patch detection.

R.Sinduja in 2008 [2], for watermarking used the classification of cracks. In this paper cracks are detected by thresholding the output of the morphological top-hat transform. Afterwards, the thin dark brush strokes, which have been misidentified as cracks are removed using a semi-automatic procedure based on region growing. The cracks are classified using an unsupervised approach, which incorporates fuzzy clustering of the patterns. This system classifies cracks using the fuzzy k-means technique.

Bruno Cornelis, Yun Yang in 2013 [4] proposed a semi-supervised crack detection method that can be used for high-dimensional acquisitions of paintings coming from different modalities. Their goal was to build a classifier that was able to discern crack pixels from the background consisting of non-crack pixels, making optimal use of the information that is provided by each modality. To accomplish this we employ a recently developed non-parametric Bayesian classifier, which uses tensor factorizations to characterize any conditional probability.

Hilda Deborah and Jon Yngve Hardeberg, in 2015 [5], studied about the crack detection task which is addressed with a spectral processing expressed in a fullband and vector approach. By using distance functions in the ordering relations and crack detection method, the metrological constraints required by such important cultural heritage objects are respected. The performances of the crack detection methods are assessed with artificial images which combine real spectral images of known properties and simple probabilistic crack model, and also with images from cracked paintings.

Roman Sizyakin along with others, in 2020 [6], propose a crack detection algorithm based on deep convolutional neural networks (CNN) that is capable of combining several imaging modalities, such as regular photographs, infrared photography and X-Ray images. Moreover, they proposed an efficient solution to improve the CNN-based localization of the actual crack boundaries and extend the CNN architecture such that areas where it makes little sense to run expensive learning models are ignored. This allowed to process large

resolution scans of paintings more efficiently and shown improvements over the state-of-the-art in crack detection methods and demonstrates the potential of our proposed method in assisting art conservators.

Fig. 2. Examples of different crack appearances in paintings.

Yuan Zeng, Yi Gong, in 2018 [3], proposed a framework for flakes detection method. The flacks considered here are irregular hole patterns and randomly distributed in an image. First they have proposed a patch based method to detect the damage regions and generate the corresponding mask.

Fig. 3. The damaged ancient painting before and after digital restoration.

Chao Yang, Xin Lu and Zhe Lin in 2017 [7], proposed a multi-scale neural patch synthesis approach based on joint optimization of image content and texture constraints, which not only preserves contextual structures but also produces high-frequency details by matching and adapting patches with the most similar mid-layer feature correlations of a deep classification network as shown in Fig. 4.

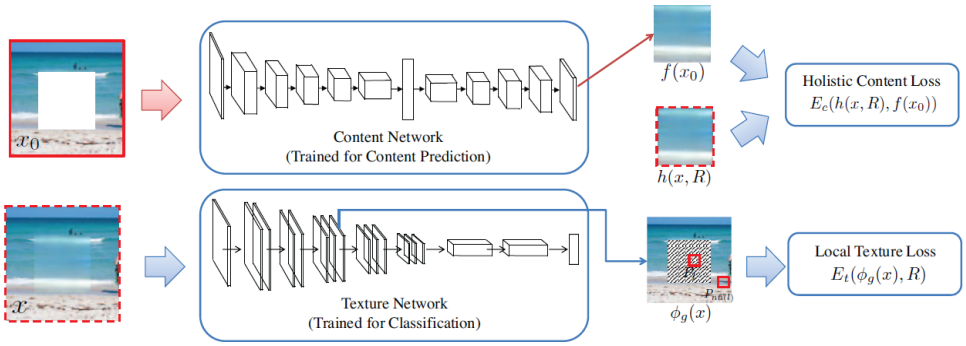

Fig. 4. Framework Overview.

III. INPAINTING

Chao Yang, Xin Lu and Zhe Lin in 2017 [7], has achieved inpainting accuracy as shown in Fig. 5. The proposed framework naturally applies to the high resolution image inpainting problem using multiscale scheme. Although the results are encouraging, the inpainting results of this method sometimes lack fine texture details, which creates visible artifacts around the border of the hole. Further they have introduced a multi-scale neural patch synthesis algorithm for high-resolution image inpainting based on the joint optimization framework.

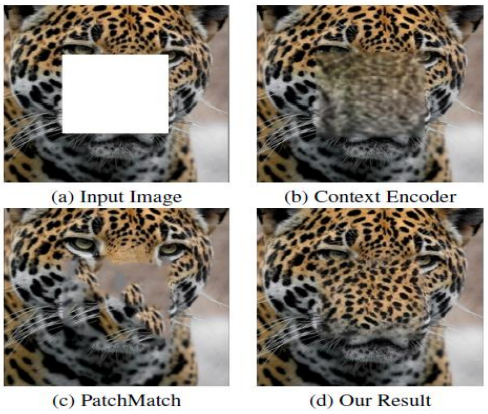

Fig. 5. Qualitative illustration of framework, (a) image with missing patch, (b) Context Encoder, (c) Content-Aware Fill using PatchMatch, (d) result of proposed inpainting method

Zeng, Yi Gong, in 2018 [3], proposed a framework for inpainting of ancient Chinese paintings via the nearest neighboring method. The framework first propose a patch based method to detect the damage regions and generate the corresponding mask. After that, a nearest neighbor based multi-scale inpainting method is performed to complete the restoration

Soo-Chang Pei and Yi-Mei Chiu in 2006 [8], presented work regarding inpainting with a color enhancement scheme to virtually restore ancient Chinese paintings in electronic form. The proposed enhancement scheme comprises two subsequent methods: background adjustment and saturation enhancement. The proposed saturation enhancement method makes colours more vivid and bright, and also improves the image contrast.

IV. CONCLUSION

We have discussed the various approaches of damage detection and image inpainting which are the two basic steps in the process of digital restoration of ancient paintings. Different approaches have its own advantages and limitations, by doing evaluative study of these research works we can choose the best one based on different parameters.

To improve the performance of digital restoration process, deep learning methods like CNN can be explored. Convolutional neural networks have been proven to be efficient and effective machine learning methods for image inpainting [7].

In the future work, deep learning based algorithms can be used for damage detection which can help to detect thin cracks as well as patches in the old paintings. Also for inpainting of missing patches of ancient paintings, the more research must have been done to select a dataset for training the model, keeping in mind the culture and philosophy behind that particular type of painting.

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