Yunnan Ancient Mural Restoration Based on Deep Learning

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Abstract. Image restoration is an important part of the research in the field of computer vision. Its purpose is to automatically recover lost content based on known content in mural images, in mural image editing, film and television special effects production, virtual reality and digital cultural heritage protection. The field has a wide range of application values. In the method of image restoration based on deep learning, the design of the deep learning network and the selection of the loss function in the training process are important contents. Each method has its own advantages and disadvantages and its scope of application. How to improve the semantics of the repair result? The correctness of sex, structure and detail has always been the direction of researchers' efforts. Based on this purpose, this paper summarizes the main features, existing problems, requirements of training samples, main application fields and references through various methods. Code. Based on the research of deep learning mural image restoration, some significant progress has been made. However, the application of deep learning in mural image restoration is still in its infancy. The main research content is only the mural image content information of the mural image itself to be repaired. Therefore, the restoration of mural image based on deep learning is still a challenging subject. How to design a universal repair network to improve the accuracy of the repair results requires more in-depth research.

Keywords: Mural Image Restoration, Deep Learning; Convolutional Neural Network, Generative Confrontation Network

1. Introduction
The restoration of the mural image based on the known information in the mural image to restore the missing part of the mural image originates from the restoration of the damaged art by the art craftsman. The early mural image restoration method is also mainly used in the art craftsman repair process. (Repair the contour first, then repair the details) Study the starting point, such as prioritizing the consistency of the boundary and the consistency of the area when designing the repair method. These methods can achieve good results in terms of small scratches, small object removal and the like. However, for the repair of large-area damaged mural images and the removal of large objects in mural images, since such methods are based on local information for diffusion repair, it is difficult to obtain ideal repair results in these applications [1-3] In essence, the art craftsman in the process of repairing art, especially in the repair of large areas, the first consideration is definitely to repair the high-level
semantic information of the object (what is the specific environment of the mural image content, what is missing, etc.) Problem) and then patch based on a large amount of a priori information that it has accumulated [4, 5].

Since the mural image restoration method has been widely studied, according to the different types of methods used to solve the problem, it can be divided into methods based on partial differential and variational, sample-based mural image restoration methods (originating from texture synthesis technology) and transformation based on The mural image restoration method of the domain and the hybrid mural image restoration method, the deep learning-based restoration method is a new type of method proposed in recent years. The method based on partial differential and variational, the method based on transform domain and the hybrid method can achieve better repair effect in the image restoration of small size damaged murals. The sample-based method can obtain relative image restoration in large area. Good results, especially where the area to be repaired can be very well represented by known sample areas. Although the research of deep learning-based repair methods is still in the initial stage, such methods have the characteristics of deep learning technology itself, that is, the deep neural network with a large number of hidden layers stacked can learn the training samples through the training of massive data. The mapping of nonlinear complex relationships, which is the problem that is expected to be solved based on the semantic restoration of mural image content in mural image restoration, especially in the repair of mural images in large areas can sometimes achieve very amazing results.

2. Relevant foundation

The mural image restoration method based on deep learning is similar to the use of deep learning technology to solve other problems, all of which involve key issues such as network structure design and how to conduct network training.

The general process of mural image restoration is to repair the unknown mural image area according to the known mural image content. The network structure design corresponding to the deep learning method needs to design a network to generate unknown information based on known information. The basis for generating a network in the deep learning method is based on a self-encoder generation network.

2.1. Self-encoder based generation network

The earliest self-encoder network can be seen as a special three-layer neural network model: input layer, presentation layer and reconstruction layer. The training of the network is to make the result of reconstruction of the reconstruction layer as close as possible to the input of the input layer. That is, the input content is first converted into a typical low-dimensional space (encoding process) and then the features of the low-dimensional space are expanded to reproduce the initial data (decoding process). Compared with the traditional encoder and decoder, the content self-encoder network eliminates the huge workload of manually extracting data features and improves the efficiency of content feature extraction. The concept of a self-encoder network was first proposed by Rumelhart et al. and applied to high-dimensional complex data processing.

Using the depth self-encoder network structure, for different input information (such as the known content of each mural image), different output information (such as missing information of each mural image) can be set for training, so that the trained network is the correspondence between the input information and the output information is established. Therefore, network training has become a problem that must be considered.

2.2. Deep network training

Bengio et al. proposed an unsupervised greedy layer-by-layer training algorithm for Deep Trusted Networks (DBN), the network structure of DBN is shown in Figure 1. which brings hope to solve the optimization problems related to deep structures. In the training of deep networks, the unsupervised layer-by-layer greedy training algorithm is used first. The layer completes the pre-training and then
uses the back propagation (BP) algorithm to optimize the system parameters of the whole neural network. This strategy significantly reduces the training difficulty of the neural network and effectively improves the BP algorithm to easily fall into the local minimum situation. In essence, DBN is similar to the self-encoder network in that it learns the representation of the input signal and restores the original signal as much as possible.

![Network structure of DBN.](image)

**Figure 1.** Network structure of DBN.

### 3. Mural image repair method based on convolution self-encoding

Originally, Pathak et al. proposed a network named Context Encoder for mural image restoration, which is similar to a self-encoding network. It is also a network of encoding-decoding processes. The first half is a series of layer-by-layer downsampling processing. The latter part is an inverse operation similar to the first half, that is, the scale of the mural image is gradually reduced during the encoding process and the scale of the mural image is gradually increased during the decoding process, eventually forming a network structure similar to the "hourglass".

In this structure, different applications add different constraints to the training of the CNN network according to the purpose of the final application. In the original coding-decoding mural image restoration method, the author used Euclidean distance and confrontation loss as constraints to train. Since the Euclidean distance is the average of all inputs and outputs, this will inevitably cause blurring. The repair method based on such a deep convolutional self-encoding network structure can be further divided into two sub-categories according to the decoder decoding result size: the decoder of the first sub-class trains for the purpose of generating a loss-area mural image block; the second sub-child The class's decoder generates an entire mural image that includes the known portion of the original mural image and the damaged region. That is, the size of the input and output mural images of the coding-decoding network of the first sub-class is inconsistent, the input is the entire mural image including the damaged area and the output is only the damaged area; the input of the encoding and decoding network of the second sub-class, The resolution of the output mural image is the same, which is the size of the entire mural image.

![Two sub-class model.](image)

**Figure 2.** Two sub-class model.
4. Deep learning evaluation of ancient mural restoration
1) Although deep neural networks have strong approximation capabilities for high-dimensional complex mapping, the semantics in mural images can be effectively extracted. However, for mural image restoration, it is necessary to accurately recover the details while obtaining the semantics of the mural image. This requires that the mural image restoration network based on deep learning needs to be able to synthesize texture components in addition to the semantic components. Therefore, how to design a network structure that combines semantic network and texture network and establish a more common network of a priori model of mural image needs further study.

2) The loss function of the deep neural network is directly related to the evaluation criteria of the repair result. The existing methods mainly use the Euclidean distance, the loss resistance, etc. as the loss function. For a specific object (such as a human face), there is structural semantics based. Loss function. But as if the confrontation loss is changed from the original cross entropy representation to the recently widely studied Wasserstein distance representation, does the semantic information of the mural image itself have a more efficient representation, especially if the boundary structure part of the mural image restoration is concerned? There is a specific loss function that is used to facilitate the convergence of training and needs further study. Therefore, the research on the network loss function of mural image repair can not only improve the convergence speed of network training, but also improve the quality of mural image restoration. This is a very meaningful research direction.

3) Design of training samples, although deep learning has strong representation ability, mural image restoration often has some professional applications, such as mural restoration, face restoration, etc. This is actually a network that is expected to be trained for a specific problem. Good results can be obtained and for specific problems, such as murals have certain rules due to their own characteristics, color types, texture details, etc. and the sample data of such specific problems is generally smaller, so it needs to be targeted. Design training samples. It is further possible to modify the trained deep network structure and perform processes such as Fine-tune to improve the generalization ability on small data sets. At present, researchers have tried to repair the image of facial murals. These methods have certain reference significance for solving other problems and can be further researched in a targeted manner.

4) The current mural image restoration directly using deep neural network is mainly limited to network training directly with low-resolution mural images, while the high-resolution mural image restoration method is relatively difficult. On the one hand, rapid training for various network structures is widely studied. On the other hand, in recent years, the computing power of GPU has been significantly improved. Therefore, the repair method for directly training high-resolution mural images is also worth studying.

5. Conclusion
At present, the mural image restoration technology based on deep learning mainly considers automatic repair. In some complex scene mural image restoration, it is worthwhile to study through some human-computer interaction or using the same type of mural image to guide the repair, which can further promote it. The practical application of rich digital mural image restoration technology.

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