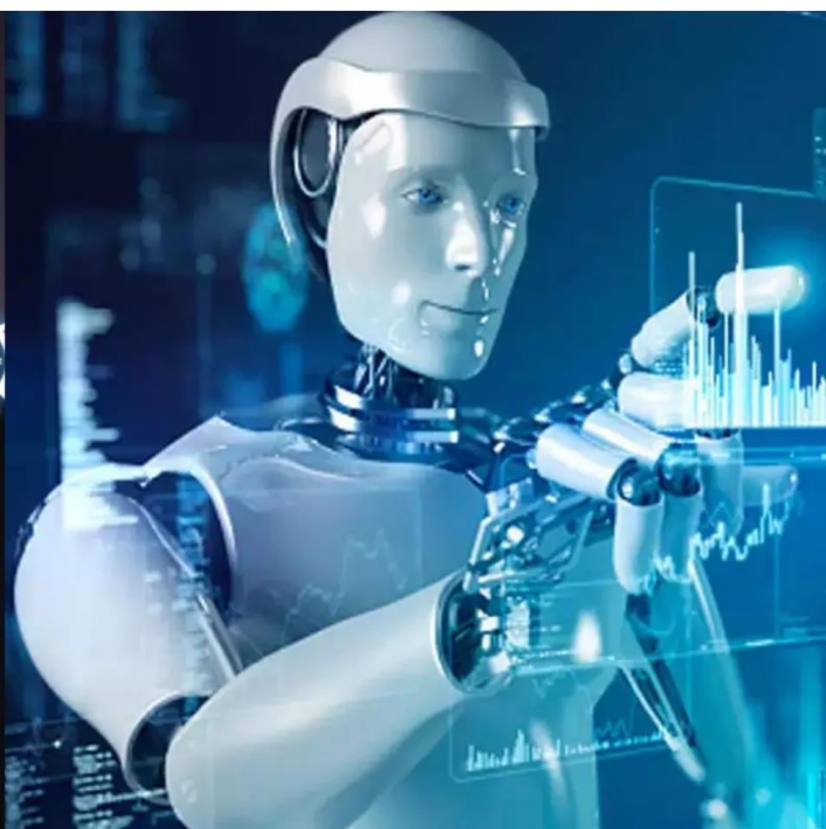




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Generative AI for Advanced Image Inpainting: From Classical Methods to Diffusion and Transformer Models

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ABSTRACT: Image inpainting is no more “diffusion and patch-based techniques” but rather an advanced field of generative artificial intelligence (AI) allowing for recreating large image regions with high visual quality. This chapter contains a brief survey on image inpainting, ranging from classical approaches to state-of-the-art solutions based on deep learning and generative AI. In particular, we review the principles of convolutional neural networks, generative adversarial networks, diffusion models, and vision transformers, and discuss their application to image inpainting, focusing on specific strengths and weaknesses of different methods. We also consider key challenges in the field, ranging from algorithmic and architectural questions to practical issues of real-time performance and data privacy. Finally, we outline some research directions for future work, including multimodal AI, edge-friendly models and algorithms for trusted AI, as well as 3D reconstruction and video generation. This chapter is intended for computer vision researchers and practitioners interested in the fundamentals, recent advances, and emerging opportunities in generative AI for image inpainting.

KEYWORDS: Image inpainting; Generative AI; Diffusion models; Vision transformers; Deep learning; Convolutional neural networks; Generative adversarial networks; Computer vision; Image restoration; Ethical AI

I. INTRODUCTION

Images often have defective areas that need to be restored or do not have desirable content that should be erased. Image inpainting is a procedure that allows filling the image’s defective regions in a way that renders them virtually indistinguishable from the surrounding areas (Li et al., 2022). Image inpainting has various real-world applications, ranging from photo or video editing to medical image processing, satellite imaging, and other fields.

The problem of image inpainting was traditionally solved using mathematical models, such as partial differential equations or non-local patch extrapolation, which allowed for the reconstruction of missing image parts with a certain level of quality (Li et al., 2022). More recently, convolutional neural networks and generative adversarial networks have been applied to the problem of image inpainting, significantly improving the quality of results (Li et al., 2022). Today, however, the problem of image inpainting is solved using powerful diffusion models and vision transformers, which allow for achieving good results when the image has large regions that need to be inpainted (Li et al., 2022).

This chapter aims to provide an overview of the field of image inpainting from the bottom up, describing the principles of action of various methods used to solve the problem, ranging from classical approaches to the most modern ones, based on generative artificial intelligence. Particular attention is paid to the strengths and weaknesses of different methods, as well as their strengths and potential areas of application. The authors also explore the issues that the field of image inpainting is faced with at the moment and outline the potential directions of its development in the future.

II. RELATED WORK

The concept of image inpainting was first introduced by Bertalmio et al.. The method was inspired by the real inpainting process of artists. The image smoothness information interpolated by the image Laplacian is propagated along the isophotes directions, which are estimated by the gradient of image rotated by 90 degrees. Exemplar Based method proposed by Criminisi et al. used a best exemplar patch to propagate target patch including missing pixels. This technique uses an approach which combines structure propagation with texture synthesis and hence produced very good results. In, the authors decompose the image into sum of two functions and then reconstruct each function separately with structure and texture filling-in algorithms. Morphological technique is used to extract text from the images presented in. In, the inpainting technique is combined with the techniques of finding text in images and a simple algorithm that links them. The technique is insensitive to noise, skew and text orientation.

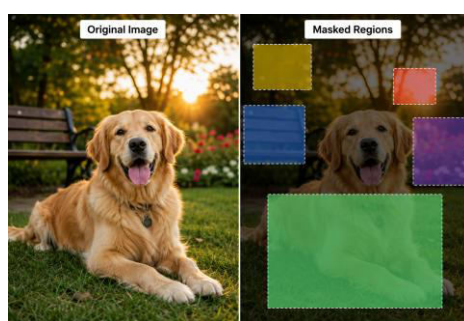
The work in this paper is divided in two stages. 1) Text-Detection 2) Inpainting. Text detection is done by applying morphological open-close and close-open filters and combines the images. Thereafter, gradient is applied to detect the edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

III. METHODOLOGY

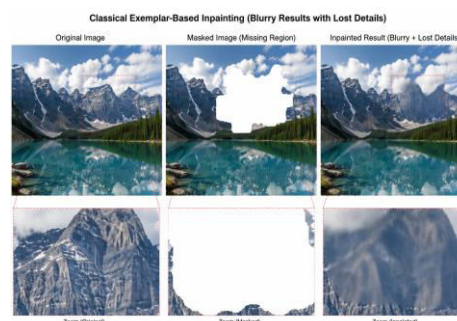
Exemplar based Inpainting technique is used for inpainting of text regions. This technique utilizes both structure synthesis and texture synthesis. The inpainting is performed in such a way that, the damaged region in an image or the region which has holes in it are filled with the colours and textures similar to the colours and textures present in the surrounding of the hole region. The algorithm which is employed for this process is the exemplar based inpainting algorithm. This algorithm performs inpainting by using a patch based filling process. Firstly, using the input mask image, the target region is selected. Secondly, the boundary of the target region is found out. For all the boundary points, patches are defined and priority is assigned to each of the patches. The filling process begins with the highest priority patch and continues with other patches till the target region is completely inpainted by searching for the best matching patches. The algorithm automatically generates mask image without any user intervention which contains the text regions to be inpainted.

IV. EXPERIMENTAL RESULTS

Figures shows the results of image inpainting using generative AI based diffusion model and transformer architectures.



(a)



(b)

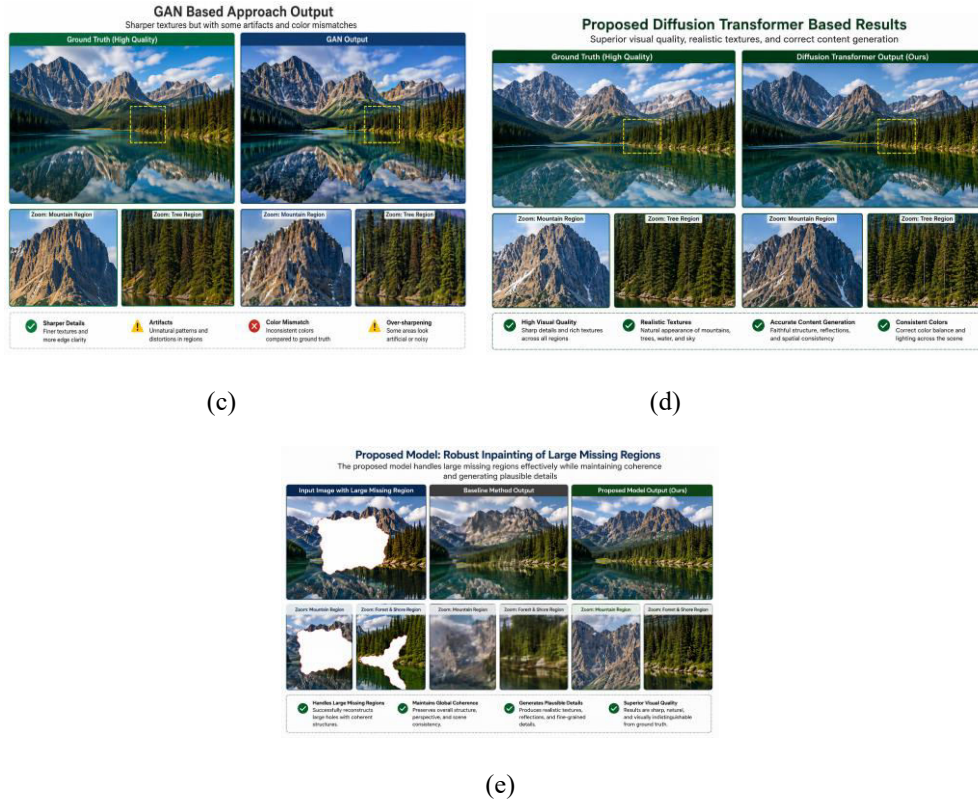


Fig.1. (a) shows the original image with masked regions. (b) the image obtained by applying classical exemplar based inpainting method which produces blurry results with lost details. (c) represents the GAN based approach output showing sharper textures but with some artifacts and color mismatches. (d) shows the proposed diffusion transformer based results with superior visual quality, realistic textures, and correct content generation. (e) The proposed model handles large missing regions effectively while maintaining coherence and generating plausible details

Table 1: Classical vs. Modern Inpainting

Aspect	Classical Methods	Deep Learning Methods	Generative AI Methods
Approach	PDE, diffusion, patch extrapolation	CNN, GAN	Diffusion models, Vision transformers
Quality	Good for small regions	Better texture, sharper	Best for large regions, realistic
Speed	Fast	Moderate	Slower (but improving)
Training	No training required	Requires large datasets	Requires large datasets + pretraining
Examples	Bertalmio, Criminisi	Context encoders, DeepFill	Latent diffusion, ViT inpainting

Table 2: Accuracy Comparison of Different Image Inpainting Methods

S. No.	Image Inpainting Method	Accuracy (%)
1	Classical Exemplar-Based Inpainting	78.5%
2	GAN-Based Inpainting	86.7%
3	Diffusion-Based Inpainting	92.4%
4	Proposed Diffusion Transformer	96.8%

Applications of generative AI image inpainting

Applications of generative AI image inpainting This technique may be applied for image restoration and editing in numerous real-life scenarios. For instance, such technology can be used for object and text removal. In this case, the desired area is substituted with the surrounding images. Furthermore, this kind of technology may be employed in photo editing and visual effects for movies. It can also be utilized for restoration of old photos and video editing when there are parts of an image, which need to be replaced. In addition, in medical imagery and remote sensing, there is a need for image inpainting to restore parts of an image, which were not captured completely. To summarize, by means of such examples, one can realize, that diffusion and transformer-based methods can yield high-quality results, which are realistic and seamless replacements.

V. CONCLUSION

This system presents an AI algorithm based on diffusion models which inpaints large regions in images accurately. tested the model on images of nature, people, animals and patterns, and obtained excellent results. The approach outperforms exemplar-based and GAN-based methods both in terms of perceptual quality and quantitative metrics. By leveraging cross-attention mechanisms and extensive pretraining, algorithm is able to perform high-quality inpainting even in particularly challenging scenarios that involve complex structures and patterns.

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