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Two-Phase Image Inpainting: Combine Edge-Fitting with PDE Inpainting

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Abstract. The digital image inpainting technology based on partial differential equations (PDEs) has become an intensive research topic over the last few years due to the mature theory and prolific numerical algorithms of PDEs. However, PDE based models are not effective when used to inpaint large missing areas of images, such as that produced by object removal. To overcome this problem, in this paper, a two-phase image inpainting method is proposed. First, some edges which cross the damaged regions are located and the missing parts of these edges are fitted by using the cubic spline interpolation. These fitted edges partition the damaged regions into some smaller damaged regions. Then these smaller regions may be inpainted by using classical PDE models. Experiment results show that the inpainting results by using the proposed method are better than those of BSCB model and TV model.

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Key words: Image inpainting, partial differential equations, edge fitting.

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1 Introduction

The task of filling in missing or damaged regions of an image is known as image inpainting which has many important applications in the area of digital image processing, visual analysis and film industry. The work has also been applied in repairing old photos, removing the scratches in old films, removing the redundant texts and objects in some scenes, magnifying images, image encoding, etc [1–3].

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The digital image inpainting technology based on partial differential equations (PDEs) has become an intensive research topic over the last few years [4–9] due to the mature theory and prolific numerical algorithms of PDEs. One basic PDE inpainting model is known as the BSCB model proposed by Bertalmio et al. [10,11]. The idea used in this model is propagating smoothly the information from the surrounding areas of the damaged region along the isophote directions to the damaged region. Chan and Shen [4,5] extended the classical TV denoising model of Rudin-Osher-Fatemi [12–14] and developed a total variation (TV) based inpainting model and the curvature driven diffusions (CDD) inpainting model from the point of view of variational principles and image prior models. In [15], Chan and Shen developed an Euler elastica (EE) inpainting algorithm based on connecting appropriate level lines by Euler elastica curves. This method turns out to be a generalization of the transportation mechanism of BSCB model and the CDD model.

However, as many researchers pointed out [16,17], these models are not effective when used to inpaint large missing areas of images, such as that produced by object removal. The reason is that the information of the outer borders of the missing areas can not be propagated into the inner pixels by current PDE models because they are far from the outer borders of missing areas [18]. To overcome this problem, in this paper, a two-phase image inpainting method is proposed. First, some edges which cross the damaged regions are located and the missing parts are fitted. These fitted edges partition the damaged regions into some smaller regions. Then these smaller regions can be inpainted by using above PDE models. Experiment results show that the inpainting results by using the proposed method are better than those of BSCB model and TV model.

The paper is organized as follows. First some classical PDE based inpainting models are reviewed. Then a two-phase inpainting method based on the combination of the cubic spline interpolation and PDE based inpainting is proposed. Finally numerical tests and some conclusions are given.

2 PDE-based image inpainting models

As depicted in Fig. 1, let Ω denote the entire domain of a damaged image, D the damaged region, where the image information is missing or damaged, $\Omega \setminus D$ the available part of the image, the inpainting boundary $\partial D \in \Omega \setminus D$.

The first PDE-based image inpainting model is proposed by Bertalmio et al., which can be described as below [10,11]:

$$\frac{\partial I}{\partial t} = \delta L \cdot \vec{N}, \tag{2.1}$$

where I is the image at time t; $\vec{N}$ represents the isophotes direction; δL is a measure of the change of certain information L being propagated along the isophotoes direction into the damaged region.