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Editorial

Advances in Variational and Partial Differential Equation-Based Models for Image Processing and Computer Vision

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Partial differential equation- (PDE-) based models have led to an entire new subdomain of image processing and analysis. The partial differential equations express continuous change, so they have long been used to formulate dynamical phenomena in many important engineering domains. Thus, they have proved their usefulness in various image processing and computer vision fields, where they have been widely applied in the last 30 years, since they offer some important advantages to these areas, such as their modelling flexibility, their strong mathematical foundation, and their numerical approximations representing reinterpretations of numerous classical image processing techniques.

Since it is very common in image processing and analysis to obtain PDE models from variational problems involving functional minimization, many PDE variational techniques have been developed in these domains. They have important advantages in both theory and computation, compared with other techniques. Variational models can achieve high speed, accuracy, and also stability. While many PDE-based image processing models follow variational principles, there also exist such PDE schemes that are not derived from variational approaches. Both variational and nonvariational partial differential equations appear in a variety of image processing and computer vision areas, successfully answering the challenges that still persist in these domains.

Thus, the nonlinear second- and fourth-order diffusion-based models represent the best denoising and restoration solution, since they remove successfully various types of noise while overcoming the undesirable effects and preserving the image details, which still constitutes a challenge in this area. Variational and nonlinear second-, third-, and fourth-order PDE-based techniques are also applied successfully in the structural inpainting domain and the image compression area that uses the inpainting results in the decompression stage. Also, a lot of effective PDE variational algorithms have been developed in the image segmentation and registration domains. Since the optical flow is successfully computed using variational methods, the video motion estimation and computer vision fields like object detection and tracking represent also important application areas of partial differential equations.

The main purpose of this special issue is to gather scientific works disseminating advanced research on several topics related to these PDE-based image processing and computer vision areas. We have received a total of 20 submissions, from authors in many countries all around the world. Since only a few of these papers have been considered appropriate enough to be published in the journal, by our editorial team, this special issue is composed of five peer-reviewed original research articles.

In the paper "Fast Video Dehazing Using Per-Pixel Minimum Adjustment", Z. Luan et al. introduce a fast video dehazing method which represents an image restoration problem. A computer vision scheme that is atmospheric scattering model is used for haze removal. The atmospheric light from this model is estimated by using a quad-tree based method. The proposed technique improves the efficiency of video dehazing and outperforms other haze removal methods.

In the paper "Efficient 3D Volume Reconstruction from a Point Cloud Using a Phase-Field Method", D. Jeong et al.

propose a PDE-based efficient 3D volume reconstruction technique from unorganized point clouds, using a phase-field method. The reconstruction is based on the 3D binary image segmentation method using a modified Allen-Cahn equation. The effectiveness of the proposed algorithm has been proved by the successful computational experiments.

The paper "Image Regularity and Fidelity Measure with a Two-Modality Potential Function", authored by W. Wang et al., describes a PDE variational model for image restoration. The authors define a strictly convex smooth potential function for this model and use it to measure the data fidelity and the regularity for image denoising and cartoon texture decomposition. Given the mathematical properties of this potential function, the proposed variational restoration approach outperforms the total variation based denoising models and works successfully for many categories of noise including Gaussian noise, impulse noise, Poisson noise, and mixed noise.

In the paper "A Lightweight Surface Reconstruction Method for Online 3D Scanning Point Cloud Data Oriented toward 3D Printing", B. Sheng et al. provide an online lightweight surface reconstruction approach composed of three algorithms: a point cloud update algorithm (PCU), a rapid iterative closest point algorithm (RICP), and an improved Poisson surface reconstruction algorithm (IPSR) that uses biharmonic-like fourth-order PDEs to repair the mesh holes on the reconstructed lightweight mesh. An online personalized customization system oriented toward 3D printing is then constructed using the proposed approach.

In the paper entitled "An Improved Fractional-order Optical Flow Model for Motion Estimation", B. Zhu et al. propose a fractional-order optical flow model that improves the Horn and Schunck optical flow model. The considered variational model for video motion estimation substitutes the brightness constraint equation of the HS model with the fractional-order Taylor series expansion and gets a fractional-order brightness constraint equation. The performed experiments demonstrate the performance of this improved variational optical flow model.

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