

PDE-based techniques for image restoration, fusion and segmentation

Habilitation thesis

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Abstract

This work presents my research activity since 2004 when I publicly defended my thesis and I got the Ph.D. title from the Technical University of Cluj-Napoca and from the University of Bordeaux 1, France. The manuscript mainly reviews my contributions in the image processing domain using the *Partial Differential Equations (PDE)* framework.

These contributions are grouped under three major research directions, as listed in the first section (*Preamble*):

- **D1.** Development of new methods for image and 3D volume data restoration and enhancement using directional diffusion techniques.
- **D2.** Development of new image and 3D data volume restoration and enhancement methods using fusion and diffusion techniques.
- **D3.** Development of new gridding and segmentation methods for cDNA microarray genomic data.

As far as direction **D1** is concerned, my major contributions are related to the development of new image restoration models that are using multiple diffusion axes and symmetric or asymmetric formulations. The novelty, with respect to state-of-the-art approaches, is the use of an orientation estimation operator that minimizes estimation errors on junctions and allows the formulation of forward or backward diffusion processes under differentiability or semi-differentiability constraints. These constraints mathematically translate the orientation estimation operator's ability to characterize local structures using a *modulo* π or a *modulo* 2π formalism. All the developed models (asymmetric PDEs for image restoration, multidirectional PDE-based models, PDE-based filters with adaptive symmetric/asymmetric smoothing actions, novel image restoration operators based on the complex shock filtering theory, PDE-models for 3D volume data restoration) are listed in the *Preamble* section, with referral to the publications supporting them. Among these publications two are in ISI quoted journals.

In the research direction **D2** I proposed a novel fusion-diffusion framework allowing the combination of the effects on non-linear PDEs acting on a unique input image and the use

of PDEs for fusing and restoring multiple input images representing the same 2D or 3D scene, that contain complementary information. These contributions (a novel fusion-diffusion framework for image restoration and enhancement, use of the framework to combine the effects of different sets of parameters of a PDE and for reducing the sensibility with respect to the stopping time, 2D and 3D models for complex degradation scenarios involving noise and blur, 2D and 3D fusion models using an inverse PDE as the fusion term and selective diffusion models for restoration) are also listed in the *Preamble* section, together with the associated publications. One of these publications is in an ISI quoted journal.

My contributions in the research direction **D3** are related to the use of PDEs for processing images representing cDNA microarrays. The proposed methods deal with grid alignment and spot segmentation and were disseminated through two publications in ISI quoted journals and a patent application (OSIM stage A2), indexed in the ISI Thomson Reuters patent database.

The first section also reviews my professional evolution since 2004, enumerates my main collaborators and lists the research grants in which I was or I am currently involved in.

The next section, *Scientific achievements*, details the aforementioned contributions grouped under the thematic research directions. For each research direction, a brief review of the main challenges and of the corresponding state-of-the-art concurrent approaches is presented in introductory subsections. Contributions are then detailed by presenting the associated theoretical models, their numerical approximations and illustrative visual and/or quantitative examples, as they were presented in the original publications.

The *Academic and professional achievements* section briefly reviews my contributions and achievements other than research, related to the following aspects: development of new courses, initiation of academic and research collaborations with the industry and with partner research and academic institutions from abroad, results and achievement in teaching and supervision of B.Sc. thesis and master dissertations, achievements in the institutional development of the faculty and of the university.

The section *Career development plan* sketches my future professional evolution. The plan is derived from a personal SWOT analysis, states my objectives and goals and the associated actions on three components: didactic, research and institutional development.

The final part of the manuscript includes a lists of references composed of 104 titles among which 34 I authored or coauthored.