PREFACE

Advances in the computational science largely contribute in medical imaging domain to help humanity. In recent decades, a lot of research tuned non-invasive techniques have been devised to serve mankind. One of them is Magnetic Resonance Imaging (MRI) which provides structural information at higher resolution even in presence of bone structures in the body. Although it is free from the ionizing ingredient, factors like electronic circuitry, patient movement etc. provoke some artifacts in imaging system considered as noise. One needs to get rid of these artifacts by means of software processing to enhance the performance of the diagnostic process. This thesis is an attempt to deal with noisy part of MRI and comply with preserving image structures such as boundary details and preventing over-smoothing. It has been observed that, in the case of MR data, one of the prominent noise follows the Rician distribution. As opposed to additive Gaussian noise, Rayleigh noise and Rician noise is signal dependent in nature due to MR image acquisition process. However, Rayleigh noise mostly exists in the background area of the magnetic resonance imaging, which occurs in brain MR images.

To address the issues of restoration and enhancement of noises present in MRI following contributions are made in this thesis:

A comprehensive literature review and comparative study of various classical as well as state-of-the art methods for restoration and enhancement of MRI is presented.

Further, this thesis focuses on the problem of design and development of filters for restoration and enhancement of MRI.

Following methods have been proposed, implemented and tested on standard dataset:

- An efficient PDE-Based nonlinear filter adapted to Rician noise for restoration and enhancement of magnetic resonance images.
- Modified complex diffusion based nonlinear filter for restoration and enhancement of magnetic resonance images.
- Orientation dependent anisotropic adaptive fuzzy diffusion based filter for restoration and enhancement of magnetic resonance images.
- PDE-Based general framework adapted to Rayleigh's, Rician's and Gaussian's distributed noise for restoration and enhancement of MRI.

Firstly, this thesis presents the proposed method which is casted into a variational framework. The introduced filter consists of two terms wherein the first term is a data fidelity term and the second term is a prior function. The first term is obtained by minimizing the negative log likelihood of Rician pdf. Since the solution of the first term is ill-posed in nature and hence a prior function is introduced which is a nonlinear anisotropic diffusion and a complex diffusion based filter. To balance the trade off between data fidelity term and prior a regularization parameter has been introduced. The performance analysis and comparative study of the proposed method with other standard methods is presented for Brain Web dataset at varying noise levels in terms of PSNR, RMSE, SSIM, and CP. From the simulation results, it is observed that the proposed method is performing better noise removal in comparison to other methods.

Secondly, this thesis focuses on the problem of orientation dependent anisotropic adaptive fuzzy diffusion based filters. During the acquisition, the MR image may be generally corrupted due to external or internal causes. The external causes lead to an additive noise pattern which follows a Gaussian distribution (pdf). Causes of internal noise in MR image are basically the intrinsic noise that is generated during the

acquisition process. Normally intrinsic noise in MR image follows the Rician distribution (pdf). The proposed method is capable to remove Gaussian as well as Rician noise from MRI using orientation dependent anisotropic adaptive fuzzy diffusion based prior. The proposed methods are casted into a variational framework as an energy functional. Euler-Lagrange minimization technique is used to derive the filters. The derived filters are adapted to the specific type of noises such as Gaussian or Rician depending on the type of noise present in the image. To deal with the ill-posedness problem of the derived filters an orientation dependent anisotropic adaptive fuzzy diffusion based prior is used because it performs better in comparison to other methods.

Finally, this thesis focuses on the problem of a partial differential equation-based general framework adapted to Rayleigh's, Rician's and Gaussian's distributed noise for restoration and enhancement of magnetic resonance images. The proposed framework is obtained by casting the noise removal problem in to a variational framework. This framework automatically identifies various type of noise present into the MRI and filters them by choosing an appropriate filter. This filter consists of two terms wherein the first term is a data likelihood term and the second term is a prior function. The first term is obtained by minimizing the negative log likelihood of the corresponding pdfs: Gaussian or Rayleigh or Rician. Further, due to the ill-posedness of the likelihood term, a prior function is needed. This chapter examines three pde based priors which include total variation (TV) based prior, anisotropic diffusion (AD) based prior and a complex diffusion (CD) based prior. A regularization parameter is used to balance the trade off between data fidelity term and prior. The finite difference scheme is used for discretization of the proposed method. The performance analysis and comparative study of the proposed method with other standard methods is presented for Brain Web dataset at varying noise levels in terms of PSNR, MSE, SSIM, and CP. From the simulation

results, it is observed that the proposed framework with CD based prior is performing better in comparison to other method and priors in consideration.

The overall thesis is organized into six chapters as follows:

Chapter 1 presents a brief introduction of the problems addressed in this thesis followed by the objectives of the thesis. The chapter concludes with a brief account on contributions of this thesis in the field of restoration and enhancement of magnetic resonance images.

Chapter 2 discusses the theoretical background for restoration and enhancement of magnetic resonance images. In this chapter, we are also given an overview of magnetic resonance images. Further, in this chapter a literature survey of prominent approaches for restoration and enhancement of magnetic resonance images are given.

Chapter 3 presents design and development of nonlinear partial differential equations based filter for restoration and enhancement of magnetic resonance images. Further, in this chapter two new methods are proposed, the first one is an efficient partial differential equation based nonlinear filter adapted to Rician noise for restoration and enhancement of magnetic resonance images and second one is the modified complex diffusion based nonlinear filter adapted to Rician noise for restoration and enhancement of magnetic resonance images.

Chapter 4 presents removal of noises from magnetic resonance images using orientation dependent anisotropic adaptive fuzzy diffusion based filters. Further, the proposed method is compared with other standard methods in terms of performance metrics and it is found that the proposed method is performing better.

Chapter 5 presents a partial differential equation based general framework adapted to Rayleigh's, Rician's and Gaussion's distributed noise for restoration and enhancement of magnetic resonance images. In this chapter, a general filter is designed which filters

out the Rayleigh's, Rician's and Gaussion's distributed noise one by one distinctly from various noise corrupted magnetic resonance images.

Chapter 6 presents conclusions and summarizes main findings of the research work. This chapter also proposes possible future perspectives of restoration and enhancement of MRI.