Chapter 1

Introduction

Highlights of the Chapter

- *Challenges in the Medical Imaging*
- *Motivation for MR imaging*
- *Objective of the Thesis*
- *Contribution of the Thesis*
- *Organisation of the Thesis*

The advancement in the field of medical imaging and the appearance of new image acquisition techniques have paved the way for the field of medical image processing. The interpretation of medical images is made using medical image processing [1]. The vital information regarding the anatomical structure of the pathological tissues is provided by the in-depth analysis of the medical images of various modalities. The automatic information retrieval from the medical images requires an efficient computer-aided approach. These computer-based approaches can help in saving the precious time of the medical practitioners and will ease the burden of the medical system [2]. Various medical imaging modalities are employed for the analysis of different diseases. The basic and the first imaging modality is X-ray. In this technique, the X radiations are penetrated inside the body and depending upon the absorption capacity of various organs, and the X-ray image is generated [3]. This technique is unable to distinguish between the overlapping soft tissues and complex structures. The computed tomography (CT) overcomes the shortcomings of X-ray by generating cross-sectional images in various planes. Ultrasound (US) or sonography is another medical imaging modality that uses sound waves for the creation of images of inside body parts [4], unlike X-ray and CT [5], which uses ionizing radiations. This modality suffers the disadvantage of poor contrast tissues. Positron emission tomography is another technique used for the determination of functional information of the organs. It uses a radioactive substance known as radiotracers for measuring changes in various physiological activities [6]. Another widely used modality is Magnetic resonance imaging (MRI) which is based on electromagnetic effects of the nucleus [7]. The scan uses a strong magnetic field and radio waves to generate images of parts of the body that can't be seen as well with X-rays, CT scans or ultrasound. It is a non-radiation technique in which the scanner utilizes the strong magnetic field and its gradients to generate images of the inside body organs. In MRI, the hydrogen atoms are used to generate macroscopic polarization, which is detected by the antennae placed closed to the subject. The advancement in MR imaging techniques such as functional and diffusion MRI enabled it to track neuronal activities and blood flow nervous system.

The present thesis utilizes MR images for segmentation and denoising applications. For diagnostic purpose MR images provides better image resolution and soft tissue contrast [8] [9]. The inverse Fourier transform of raw data converts it in to either 2-D or 3-D format depending on the application. MRI offers various pulse sequences which can be helpful in analysing various anatomical and pathological changes and can produce relevant information [10]. Present work focuses on post processing of MR images for making them more suitable for medical analysis. Furthermore, the thesis focuses on the classification of X-ray and CT images for the detection of various diseases.

1.1 Challenges in the Medical Imaging

The medical imaging data contains plenty of information that can be retrieved using various medical image analysis methods. The accurate identification of the disease is important for planning the diagnosis [11]. Medical Imaging techniques are playing a vital role in such analysis. The radiologists take in to account the spatial and intensity information of the pixels for any anatomical and pathological change [12]. The recent advances in the field of medical imaging have paved the way for many algorithms and artificial intelligence models to address imaging problems more efficiently [13]. Concurrently, many issues have arisen in this field. Firstly, the methods which can analyse heterogenous data is needed. Secondly, adaptive image analysis technology is needed for specific tasks. Thirdly, imaging methods must be able to produce patient-specific models from medical images. Lastly, efficient ground truth generation methods are required to match the rising demand for automatic methods. Moreover, the medical image data suffers the following issues which create problems in the diagnosis: 1) The noise in the images [14] [15], 2) heterogeneous intensity and contrast levels [16], 3) difficulty in early diagnosis of the disease due to clear distinction between the normal and the healthy tissues [17], 4) Artifacts produced during the image acquisition [18].

1.2 Motivation for MR imaging

The basic principle of MRI incorporates the processing of protons present in the human body under the presence of the external magnetic field. When the RF pulses are applied to the protons, the protons release their energy in the form of electromagnetic waves, which is captured by the receiver coils of the scanner. The electromagnetic components contain phase and frequency components. For the image generation, the inverse Fourier transform of raw data is taken, and the real-time image is formed. The receiving coils of the MRI scanner are affected by the heating effects. These heating effects induce noise in the MR images. The quality of the MR images often gets degraded while imaging acquisition. The degradation can be because of the artefacts, which can be related to hardware, software, patient and physics [19]. The power supply disturbances and thermal agitation are related to hardware artefacts, while intensity inhomogeneity and error in decoding pulses incorporates software artefacts. The body movement of the patient, blood flow and holding of breath are termed patient-related artefacts.

The Gibbs rings, magnetic susceptibility etc., constitutes physics-related artefacts [20]. These artefacts affect the information contained in the MR images, and hence, in turn, it affects the diagnosis of the disease. The artefacts may lead to misinterpretation by the clinical experts. The radiologists tend to analyse the specific region of interests for correct diagnosis of the disease. For such purposes, medical image segmentation becomes necessary for analysing a specific organ or tissue. The noisy and artefact induced images create several problems in the proper segmentation of medical images [21]. For enhancing the quality of the MR images, the essential step is to get the denoised images so that other post-processing steps such as segmentation, registration etc., can be reliably computed on the images. Noise pixels creates the problem in identifying the correct boundary details. Hence noise makes edge identification difficult. Thus the image enhancement models with the capability of preserving the information contents while suppressing the noisy components are needed [22]. Further, the images segmentation model with efficient segmentation capabilities is needed to distinguish the normal tissues from the unhealthy tissues. The rapid advancement in the field of deep learning has become a boon for solving complex issues like denoising and segmentation. The deep learning-based method is becoming important nowadays because of its capability of automatic extraction of features and producing reliable results. Thus, for the above-mentioned issues, reliable deep learning-based models are needed with the following capabilities:

1. The model should denoise the images with the least possible alteration in other essential information contents [23].

2. The segmentation model can segment the desired region of interest, such as a tumour or cancerous regions, without affecting the normal tissues. The model should produce fine boundary details, i.e. it should preserve the accurate boundary details [24].

3. The deep learning model for proper classification of various images of the same domain with minimum misclassification errors [25].

1.3 Objective of the Thesis

The fundamental objective of this thesis is to segment and classification of the medical images using deep learning techniques. It also includes algorithm for improved denoising of the MR images and produce the noise free images for the robust diagnosis of the disease. Thus, the prime intent of this work is towards reducing the uncertainty caused by the noise, followed by classification of the biomedical images so that the related diseases can be identified precisely. The research focuses on improving the segmentation quality by reducing the boundary prediction errors. The motivation for this work is to provide reliable information from the medical images planning the diagnosis. In this view, this thesis aims to fulfil the following objectives:

1) To develop denoising models based on deep learning for producing reliable denoised medical images by reducing the uncertainties caused by the noise.
2) To develop the deep learning-based models for accurate delineation of the pathological structures, which are to be analysed for the diagnosis of the disease.
3) To develop a medical image classification model using the deep learning approach to classify of images infected by various diseases.
4) To develop a transfer learning-based model for the classification of medical images contaminated with the disease having nearly correlated features.

1.4 Contribution of the Thesis

This thesis contributes to the necessary theory and implementations to develop deep learning-based models for segmentation, denoising and classification of biomedical images. The thesis has shown different clinical applications and has developed the following approaches:

- Development of deep learning-based models with modifications on conventional networks for accurate and precise delineation of the affected regions.
- Implementation of deep learning-based model for segmentation of noisy MR images.
- Development of denoising model for reducing the uncertainties caused by the Rician noise in the MR images.
- Development of a deep learning-based model for precise classification of medical images infected with the diseases of nearly identical features.
- Transfer learning-based model for classification of medical images to identify the specific disease features.

1.5 Organisation of the Thesis

The remaining thesis has been organized in the following manner in order to provide detailed information regarding the ideas that have been mentioned beforehand. The structure of the thesis is given as follows:

Chapter 2 presents the background and literature review of the work. The chapter gives a brief idea of deep learning networks utilized for segmentation, denoising and classification of medical images. This chapter also discusses a brief overview of the methods used previously and their utilization in medical image analysis.

Chapter 3 presents an architecture based on conventional SegNet incorporated using internal residual connections, Cross Channel Normalization and parametric RELU. Further, the proposed model is compared with other established methods.

Chapter 4 presents a segmentation network based on depth wise separable convolutions and group normalization in SegNet architecture for the segmentation of brain tumour and skin cancer. The network segmented not only the public dataset but also the real-time brain tumour MR images. This chapter showcases the effectiveness of depth wise separable convolution over standard convolution in medical image segmentation.

Chapter 5 presents an end-to-end trainable deep learning network with noise stifler arrangement for segmentation of noisy images. This chapter deals with the MR images corrupted with Rician, which are directly segmented using the proposed network and remarkable improvement in the results was noted compared with other established methods.

Chapter 6 presents a denoising model incorporated using depthwise separable convolutions, internal residual connections, Local Response Normalization and parametric RELU on DnCNN base architecture. The incorporation of depthwise separable convolution instead of normal convolution in the proposed architecture gave a remarkable improvement.

Chapter 7 presents an end-to-end trainable classifier based on the SegNet feature extraction model. This model was used to classify the images infected with covid-19 and viral pneumonia. The network efficiently captured the two strongly related features, and remarkable improvement in the results was obtained. Moreover, this chapter also presents a transfer learning-based SVM classifier that extracts features from various deep neural networks to classify images infected with Covid-19. The features obtained from MobileNet V2 architecture and other five established networks were used to train the SVM classifier.

Chapter 8 summarizes the overall contribution and points out the main achievement of the thesis and its future directions, which might be the interest in further research.