Chapter 5
Deep Learning Models for Biomedical Image Analysis

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ABSTRACT

Biomedical image analysis has become critically important to the public health and welfare. However, analyzing biomedical images is time-consuming and labor-intensive, and has long been performed manually by highly trained human experts. As a result, there has been an increasing interest in applying machine learning to automate biomedical image analysis. Recent progress in deep learning research has catalyzed the development of machine learning in learning discriminative features from data with minimum human intervention. Many deep learning models have been designed and achieved superior performance in various data analysis applications. This chapter starts with the basic of deep learning models and some practical strategies for handling biomedical image applications with limited data. After that, case studies of deep feature extraction for gene expression pattern image annotations, imaging data completion for brain disease diagnosis, and segmentation of infant brain tissue images are discussed to demonstrate the effectiveness of deep learning in biomedical image analysis.

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INTRODUCTION

Biomedical image analysis is critically important to the public health and welfare. The advancements in imaging devices such as Computed Tomography (CT) scans, Magnetic Resonance Imaging (MRI), and X-ray, have made biomedical images readily available to the public for early diagnosis and medical treatment of diseases. On the other hand, analyzing biomedical images is a complex task that has long been performed manually by highly-trained experts such as radiologists and pathologists. This manual process is time-consuming and laborious which may involve wrong interpretation due to fatigue or stress in human experts. Hence, machine learning approaches have been used to assist in biomedical image analysis.

In machine learning, finding informative features for data representation is the key step in learning from data. Over the past several decades, task-specific features have been handcrafted by human experts based on their domain expertise and engineering skills. The barrier to designing appropriate features was generally high for non-experts in their own applications. Recent breakthroughs in deep learning research overcome this barrier by moving feature extraction from the human side to the computer side (LeCun et al., 2015; Goodfellow et al., 2016). Inspired by biological neural systems, deep learning models consist of deep neuromorphic processing layers to take into account both feature extraction and domain-specific learning at the same time. Thus deep learning is capable of obtaining a hierarchy of increasingly complex features directly from data with minimum human intervention, which greatly helps to achieve accurate models for various data analysis applications.

Regarding image-related tasks, Convolution Neural Network (CNN) is one particular architecture of deep learning. A typical CNN architecture incorporates convolutional layers and pooling layers to reduce the number of network parameters while learning from spatial image information. Motivated by the efficacy of the deep CNN architecture, many CNN-based deep learning models have been designed and achieved superior performance in image-related tasks. For example, (Krizhevsky et al., 2012) presented a CNN-based model (denoted as AlexNet) which won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) 2012 with a Top-5 test accuracy of 84.6% in its image classification task. It is worth noting that AlexNet significantly outperformed the 2nd place using the traditional bag of words approach with the accuracy of 73.8%. Later, (He et al., 2016) proposed a

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