Chapter 13
Magnetic Resonance Image Analysis for Brain CAD Systems with Machine Learning

Hidetaka Arimura
Kyushu University, Japan

Chiaki Tokunaga
Kyushu University, Japan

Yasuo Yamashita
Kyushu University, Japan

Jumpei Kuwazuru
Kyushu University, Japan

ABSTRACT

This chapter describes the image analysis for brain Computer-Aided Diagnosis (CAD) systems with machine learning techniques, which could assist radiologists in the detection of such brain diseases as asymptomatic unruptured aneurysms, Alzheimer's Disease (AD), vascular dementia, and Multiple Sclerosis (MS) by magnetic resonance imaging. Image analysis in CAD systems consists of image enhancement, initial detection, and image feature extraction, including segmentation. In addition, the authors review the classification of true and false positives using machine learning techniques, as well as the evaluation methods and development cycle for CAD systems.

BACKGROUND

The number of patients with brain diseases including stroke and some dementing disorders is expected to increase with the rise in average longevity in developed countries. For instance, the average lifespan in Japan was 86 years for females and 79 for males in 2008. A routine brain check-up known as the "Brain Dock" has become popular in Japan, because Japanese are concerned about stroke, dementia, and various other neurological disorders that are becoming more prevalent in their rapidly aging society. The aim of the Brain Dock is to detect or classify

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asymptomatic brain diseases in their early stages (e.g., asymptomatic lacunar infarction) unruptured intracranial aneurysms, Alzheimer's Disease (AD) and vascular dementia, in order to prevent or slow their progression. Magnetic Resonance Imaging (MRI) sequences including T1- and T2-weighted imaging, Fluid Attenuated Inversion Recovery (FLAIR), and MR Angiography (MRA) have generally been employed for imaging of brain diseases. However, it would be very difficult for general radiologists to detect or classify the small number of images with abnormalities among the huge number of images acquired from healthy people undergoing the Brain Dock check-up. In other words, it could be possible to miss the lesions of patients in medical images, because of their heavy workloads. In addition, the number of images that radiologists must diagnose has increased rapidly, because magnetic resonance (MR) images have shifted from two-dimensional (2D) images to three-dimensional (3D) images with higher magnetic field strengths (e.g., 3T). Therefore, in recent years, various types of brain Computer-Aided Diagnosis (CAD) methods have been developed by a number of researchers, including our group, using brain MR images based on several types of machine learning classifiers (Arimura, 2009).

Figure 1 shows a flowchart of general CAD systems, which consist of three steps including preprocessing, feature extraction, and classification. The CAD systems are designed to provide a "second opinion" for radiologists, rather than an output "decision," since this final decision should of course be made by the radiologists themselves. In general, there are two types of CAD systems for brain evaluation (i.e., systems that detect lesions and those that differentiate diseases). For instance, objective lesions that can be detected by these systems include intracranial aneurysms or multiple sclerosis, whereas objective diseases to be differentiated include AD or vascular dementia. Brain CAD systems can provide radiologists with a "second opinion" to assist them in the diagnosis of brain diseases. Consequently, radiologists expect that CAD systems can improve their diagnostic abilities based on synergistic effects between the radiologist and the computer with medical image analysis and machine learning techniques. Therefore, the CAD systems should have abilities similar to the radiologists in terms of learning and recognition of brain diseases. For this reason, pattern recognition techniques including machine learning play important roles in the development of CAD systems.

Pattern recognition is the act of extracting features from objects (e.g. lesions) in raw data and making a decision based on a classifier output, such as classifying each object into one of the possible categories of various patterns (Duda, 2000). Machine learning is a pattern recognition technique, and supervised machine learning allows a computer program to learn how to accomplish a task by following the examples provided by a learning algorithm. The classification accuracy of machine learning is substantially dependent on image feature extraction, including image segmentation.

In this chapter, the authors describe the image analysis in brain CAD systems for machine learning techniques, which could assist radiologists in the detection of brain diseases using magnetic resonance images. Image analysis in CAD systems consists of image enhancement, initial detection, and image feature extraction including segmentation. In addition to describing these processes, the authors review the classification of true and false positives using machine learning techniques, as well as the evaluation methods and development cycle for CAD systems.

IMAGE FEATURE EXTRACTION

The aim of the image feature analysis or feature extraction is to characterize an object (lesion or anatomical structure) to be recognized by measurements based on a segmented region, whose values