Chapter 2
An Overview of Machine Learning in Medical Image Analysis:
Trends in Health Informatics

Anand Narasimhamurthy
BITS Pilani – Hyderabad, India

ABSTRACT

Medical image analysis is an area which has witnessed an increased use of machine learning in recent times. In this chapter, the authors attempt to provide an overview of applications of machine learning techniques to medical imaging problems, focusing on some of the recent work. The target audience comprises of practitioners, engineers, students and researchers working on medical image analysis, no prior knowledge of machine learning is assumed. Although the stress is mostly on medical imaging problems, applications of machine learning to other proximal areas will also be elucidated briefly. Health informatics is a relatively new area which deals with mining large amounts of data to gain useful insights. Some of the common challenges in health informatics will be briefly touched upon and some of the efforts in related directions will be outlined.

INTRODUCTION

Machine Learning (ML) aspires to provide computational methods for accumulating, updating and changing knowledge in the intelligent systems and particular learning mechanisms that assist to induce knowledge from the data. It is useful in cases where direct algorithmic solutions are unavailable, there is lack of formal models, or the knowledge about the application domain is inadequately defined. Although the term machine learning is widely used, a precise definition is elusive. Wernick et al. (2010) define machine learning as a unified concept subsuming various important problems in statistical methods of automated decision making and modeling and being concerned with

1. The development of algorithms that quantify relationships within existing data, and
2. The use of these identified patterns to make predictions based on new data.

Machine learning is closely allied with disciplines such as pattern recognition and data mining; it utilizes techniques from areas such as numerical optimization and computational statistics. It is thus convenient to think of machine learning as an "umbrella" encompassing various methods and techniques. Figure 1 illustrates the overlap between the various disciplines taken from a data mining primer course SAS Institute offered in 1998. While this illustrates the considerable overlap between the various disciplines, considering that machine learning as well as the other allied disciplines are evolving continuously, we must expect the diagram to change almost year to year or even become irrelevant. Machine learning and data mining overlap significantly, many of the sub tasks and techniques are common; some authors prefer to make a distinction in that data mining is considered to focus more on exploratory analysis. Machine learning and pattern recognition can be considered as two facets of the same field (Bishop, 2006). In its initial phases at least, pattern recognition was considered as a spin-off of Artificial Intelligence (the diagram in Figure 1 also suggests this); however they have evolved along different directions, and it is fair to say that pattern recognition and artificial intelligence techniques in use at present are significantly different. Artificial Intelligence (AI) is predominantly rule based while pattern recognition tends to favor statistical methods. The techniques in these disciplines are not mutually exclusive though. Neural networks which were initially developed within the AI community are an integral part of pattern recognition. Deep Learning (Hinton, Osindero & Teh, 2006) can be considered as a modern update to Artificial Neural Networks, although the foundations date back to 1950s and 60s, there have been significant developments since 2006 and as a result Deep Learning methods are being used extensively in many applications.

A practical way to think of machine learning is in terms the tasks involved in an actual application. Almost all machine learning tasks include the steps of pre-processing and feature extraction. Pre-processing may include cleaning up noisy data, dealing with missing fields and other steps required to convert the raw data to a more suitable form. The feature extraction step consists of extracting and/or computing the required attributes relevant for the specific problem. Note that there may be additional computations applied to the data. These may include applying transformations, dimensionality reduction and feature selection to name

Figure 1. A diagram illustrating overlap between various disciplines
Source: Looking backwards, looking forwards: SAS, data mining, and machine learning, Polly Mitchell-Guthrie, August 22, 2014.
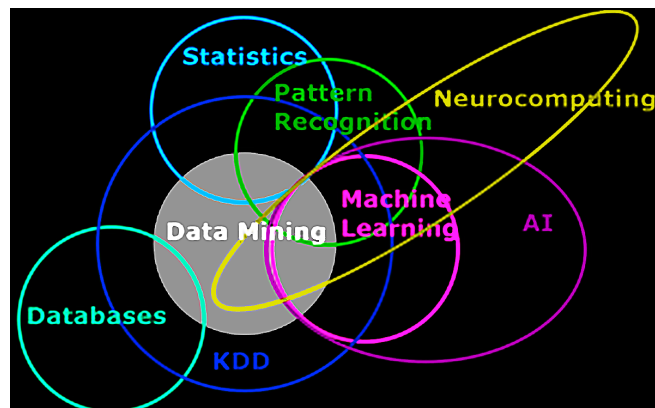
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