Chapter 8.9
From Biomedical Image Analysis to Biomedical Image Understanding Using Machine Learning

Eduardo Romero
National University of Colombia, Colombia

Fabio González
National University of Colombia, Colombia

ABSTRACT

This chapter introduces the reader into the main topics covered by the book: biomedical images, biomedical image analysis and machine learning. The general concepts of each topic are presented and the most representative techniques are briefly discussed. Nevertheless, the chapter focuses on the problem of image understanding (i.e., the problem of mapping the low-level image visual content to its high-level semantic meaning). The chapter discusses different important biomedical problems, such as computer assisted diagnosis, biomedical image retrieval, image-user interaction and medical image navigation, which require solutions involving image understanding. Image understanding, thought of as the strategy to associate semantic meaning to the image visual contents, is a difficult problem that opens up many research challenges. In the context of actual biomedical problems, this is probably an invaluable tool for improving the amount of knowledge that medical doctors are currently extracting from their day-to-day work. Finally, the chapter explores some general ideas that may guide the future research in the field.

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INTRODUCTION

Medical Images are at the base of many routine clinical decisions and their influence has practically not stopped to increase at any field of the Medicine. This trend has taken over different disciplines such as Cardiology, in which tagged cardiac magnetic resonance allows three-dimensional motion estimation, or radiology, in which texture and shape analysis techniques facilitate diagnosis of breast cancer with a simple mammography or three-dimensional visualization of any organ using computed tomography (CT) or magnetic resonance imaging (MRI). The term "Medical Images" has been used exclusively for images that support tasks associated to the medical practice such as diagnosis, treatment and follow-up. Biomedical images stand for a wider concept since it comprises any visual registering of a biological phenomenon so that they include not only medical images, but also many other image types acquired from biological systems.

From the last decade on, computers have become an invaluable tool for supporting medical image acquisition, processing, organization and analysis. Different tasks have been automated with different degrees of success. Several techniques have been applied to these automated tasks, which cover some domains including signal processing, statistics, machine learning (ML) and variable combinations of them. ML techniques have entailed automated approaches with a decision power which has shown to be very useful in real contexts, for example when parasite stages in the intra-cell cycle have to be determined (Díaz et al., 2009) or two brains have to be compared so that both are deformed to a template and an ideal partition has to be set for each (Fan et al., 2007). In general, ML techniques attempt to find patterns in data that allow to build descriptive or predictive models. One of the main advantages of ML methods is that they are able to automatically find non-obvious, complex relationships between data that, otherwise, are usually found by an extensive knowledge of the problem. Models can then be much more easily inferred from these relationships.

The main goal of this chapter is to present a global picture of the intersection between complex real biomedical problems and machine learning methods, which by the way serves as an introduction to the book. The rapid advance of the machine learning field has produced powerful techniques to solve different particular image analysis problems. However, the most important problem is still unsolved, i.e., the design of a system able to fully understand the meaning of an arbitrary image and this is the main concern of this chapter. Consequently, the chapter also presents our insights into how to approach this problem, in other words, how to move from image analysis to full image understanding in terms of the analysis of the image contents and the image-user interaction.

BIOMEDICAL IMAGES

The term "biomedical images" denotes digital images captured from living beings or parts of living beings, with structural or functional information to be analyzed, documented, annotated and formalized. This type of images constitutes the foundation of any knowledge in life sciences, they give support to the medical diagnosis, medical treatment or follow-up as well as to medical and biological research. Images are indeed a large part of the biomedical knowledge which is multimodal by nature. It combines visual structural or functional information with many different types of information. Knowledge in life sciences has been made up by integrating visual information with different physiological analysis techniques related to a particular anatomical structure.

Biomedical images are acquired using different mechanisms that range from simple, e.g. a digital camera coupled with a conventional optical microscope, to complex, e.g. specialized equipment for Positron Emission Tomography (PET). A complete account of the different biomedical image types would require a complete volume only devoted to it and clearly exceeds the scope of this chapter. However, we present a brief list of some of the most representative types of biomedical images (the interested reader may refer to (Bankman, 2000; Buxton, 2003) for further details):