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

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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.

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 mammo
graphy 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 be-
come 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 automatic-
ly 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 power-
ful 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 infor-
mation 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, med-
cal treatment or follow-up as well as to medical
and biological research. Images are indeed a large
part of the biomedical knowledge which is multi-
modal 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 micro-
scope, 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):
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