Chapter 6
Automated Diagnostics of Coronary Artery Disease:
Long-Term Results and Recent Advancements

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ABSTRACT

The authors present results and the latest advancement in their long-term study on using image processing and data mining methods in medical image analysis in general, and in clinical diagnostics of coronary artery disease in particular. Since the evaluation of modern medical images is often difficult and time-consuming, authors integrate advanced analytical and decision support tools in diagnostic process. Partial diagnostic results, frequently obtained from tests with substantial imperfections, can be thus integrated in ultimate diagnostic conclusion about the probability of disease for a given patient. Authors study various topics, such as improving the predictive power of clinical tests by utilizing pre-test and post-test probabilities, texture representation, multi-resolution feature extraction, feature construction and data mining algorithms that significantly outperform the medical practice. During their long-term study (1995-2011) authors achieved, among other minor results, two really significant milestones. The first was achieved by using machine learning to significantly increase post-test diagnostic probabilities with respect to expert physicians. The second, even more significant result utilizes various advanced data analysis techniques, such as automatic multi-resolution image parameterization combined with feature extraction and machine learning methods to significantly improve on all aspects of diagnostic performance. With the proposed approach clinical results are significantly as well as fully automatically, improved throughout the study. Overall, the most significant result of the work is an improvement in the diagnostic power of the whole diagnostic process. The approach supports, but does not replace, physicians' diagnostic process, and can assist in decisions on the cost-effectiveness of diagnostic tests.

INTRODUCTION

Internal medicine in general and cardiovascular medicine in particular utilize various diagnostic imaging tests to help physicians identify various problems and abnormalities. Such diagnostic tests produce structural and functional images of the insides of the human body. The choice of imaging technology depends on exhibited symptoms, the part of the body being examined, its cost and availability. X-rays, computer tomography (CT) scans, nuclear medicine scans (including scintigraphy), magnetic resonance imaging (MRI) scans and ultrasound are all types of diagnostic imaging.

Many imaging tests are painless and noninvasive. Some are slightly uncomfortable, as they require the patient to stay still for a long time inside a machine. Certain tests involve radiation, but these are generally considered safe because the dosage is very low. In some imaging tests, an implement (a tiny camera or other sensing device) is attached to a long, thin tube and inserted in the body. These procedures are quite unpleasant and often require anesthesia. If possible, such procedures should preferably be substituted with less invasive ones.

Cardiovascular diseases, specifically coronary artery disease (CAD), are among the developed world's premier causes of mortality. Currently, cardiovascular disease diagnostics rely on diagnostic imaging tests that require expensive, specialized equipment and trained personnel (both technicians and physicians) for efficient operation.

The aim of our long-term research is to improve the diagnostics of CAD from a computational perspective. Our early research on this topic, conducted between 1995 and 1998 (Kukar et al., 1999) showed that machine learning methods may enable objective interpretation of available diagnostic images and, as a result, increase the accuracy and reliability of the diagnostic process. Experiments conducted with various machine learning algorithms showed that these were able to exceed performance levels of clinicians.

The algorithms were also extended to deal with non-uniform misclassification costs in order to perform ROC analysis and control the trade-off between sensitivity and specificity. ROC analysis showed significant improvements of sensitivity and specificity of machine learning algorithms compared to the performance of clinicians. The predictive power of standard tests was therefore significantly improved using machine learning techniques. The major bottleneck of this study was that all data, including evaluation of diagnostic images, had to be provided by expert physicians; this caused long delays in data acquisition and a certain reluctance to accept the procedure in everyday practice.

In the present study (2006-2011), we alleviate the data acquisition problem by introducing algorithms for completely automatic evaluation (parameterization) of diagnostic images and for suggesting the most useful (informative) resolutions (Kukar et al., 2007). We also utilize a feature extraction method (principal component analysis) and machine learning/data mining techniques on extracted features that both aid in achieving excellent result. We describe the methodology used, relate results of both studies, and evaluate our contributions.

BACKGROUND

Coronary Artery Disease

Coronary artery disease is usually a consequence of the accumulation of atheromatous plaques within the walls of the coronary arteries that supply the myocardium with oxygen. While the symptoms and signs of coronary artery disease are easily observable in advanced stages of disease, most individuals with coronary artery disease show no evidence of disease until the first onset of symptoms finally arises, often as a sudden heart attack. As the coronary artery disease progresses, it may cause a near-complete obstruction of the coronary

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