Chapter 8.7
New Developments in Intracoronary Ultrasound Processing

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ABSTRACT

Intracoronary Ultrasound (ICUS) imaging is an intravascular catheter-based technique which provides real-time, high resolution, cross-sectional images of coronary arteries. In these images the lumen, the media-adventitia border, the plaque burden and the composition of the plaque can be identified. Conventionally, ICUS border detection is performed manually. However, this process is laborious and time consuming. To enhance the clinical applicability of ICUS, several automated algorithms have been developed for fast ICUS segmentation and characterisation of the type of the plaque. In this chapter the authors present an overview on the developments in ICUS processing and they describe advanced methodologies which fuse ICUS and X-ray angiographic data in order to overcome indigenous limitations of ICUS imaging and provide complete and geometrically correct coronary reconstruction.

INTRODUCTION

Accurate assessment of luminal pathology is useful for the diagnosis and treatment of coronary artery disease. The traditional method used for the depiction of coronary artery morphology is coronary angiography, which provides two–dimensional (2-D) views of the luminal silhouette. Major limitation of this modality is its inability to provide information regarding the plaque burden and the composition of the plaque, data which are useful to guide treatment and estimate prognosis.

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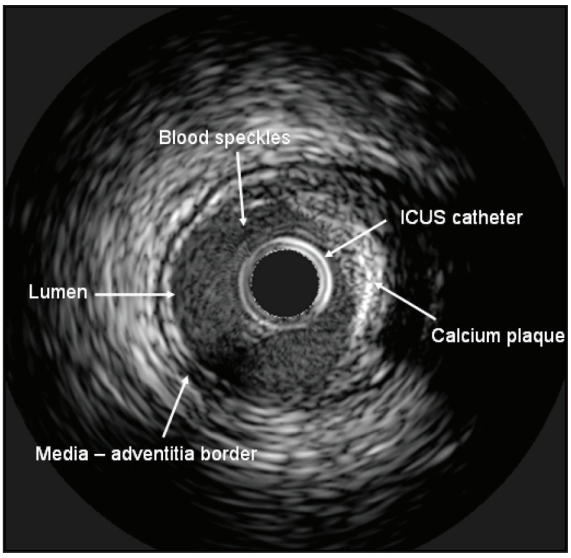
To overcome these limitations intracoronary ultrasound (ICUS) has been introduced. ICUS requires the insertion of a catheter, within the coronary artery. At the tip of the catheter there is a transducer which transmits ultrasound signal perpendicular to its axis. There are two types of ICUS systems: the "mechanical" and the "electronic" ICUS systems. In mechanical systems a single rotating transducer, at 1800 rpm (30 revolutions per second), sweeps a high frequency (20 – 40 MHz) ultrasound signal perpendicular to the axis of the catheter, while in electronic systems there is an array of small crystals which have been programmed so that one set of crystals to transmit and the other to receive simultaneously. In both systems cross–sectional images of the coronary artery are produced by detecting the reflections of the ultrasound signal while this is passing through the vessel. As the ICUS catheter is pulled–back (either manually or by a motorized pull–back device) a series of images is generated. In each image, the luminal border, the outer vessel wall border (in the text the term media–adventitia border is used), the stent border, the plaque and the composition of the plaque can be identified and accurate measurements can be obtained (Mintz et al., 2001).

In ICUS images there are often several artefacts which may reduce the ability to identify the regions of interest (Figure 1). These artefacts include: the non–uniform rotational distortion which appears only in the mechanical ICUS systems, the ring down artefact (a bright halo surrounding the transducer) that is due to a high amplitude of the ultrasound signal, the guide wire artefact, the near field artefact, the blood speckles artefact, etc. (Nissen et al., 1993).

Initially, ICUS border detection was performed manually. However, it became apparent that this process is laborious, time consuming and can be unreliable in the hands of inexperienced operators. Therefore, there was an emerging interest in the development of fast and accurate (semi-) automated segmentation algorithms which would

Figure 1. Structures and artefacts observed in an ICUS image



enhance the clinical applicability of ICUS. These algorithms had to face several challenges mostly caused by the high noise content, the low image resolution, the non–uniform luminance and contrast as well as the presence of the above mentioned artefacts.

Another problem that needed to be addressed was the reliable identification of the type of the plaque as well as the integration of the detected ICUS borders into a 3-D object which would represent the coronary vessel. Some of the earlier work on the 3-D reconstruction and visualization of the ICUS sequence assumed that the vessels were straight. However, with this assumption, ICUS could not provide any information on the 3-D arterial geometry or the spatial orientation of the plaque onto the artery. To overcome these limitations fusion of biplane angiographic data and ICUS has been proposed.

In this chapter we attempt to present an overview of the developments in ICUS processing. This review is organised as follows: in the next section we describe the segmentation algorithms which have been introduced for ICUS border detection and plaque characterization. We also