Towards Dynamic Fitness Based Partitioning for IntraVascular UltraSound Image Analysis

Rui Li[1], Jeroen Eggermont[2], Michael T.M. Emmerich[1], Ernst G.P. Bovenkamp[2], Thomas Bäck[1], Jouke Dijkstra[2], and Johan H.C. Reiber[2]

[1] Natural Computing Group, Leiden University, P.O. Box 9512, 2300 RA Leiden, The Netherlands
{ruili,emmerich,baeck}@liacs.nl

[2] Division of Image Processing, Department of Radiology C2S, Leiden University Medical Center, P.O. Box 9600, 2300 RC Leiden, The Netherlands
{J.Eggermont,E.G.P.Bovenkamp,J.Dijkstra, J.H.C.Reiber}@lumc.nl

Abstract. This paper discusses a study towards dynamic fitness based partitioning in IntraVascular UltraSound (IVUS) image analysis. Mixed-Integer Evolution Strategies (MI-ES) have recently been successfully used to optimize control parameters of a multi-agent image interpretation system for IVUS images lumen detection. However, because of complex interpretation contexts, it is impossible to find one single solution which works well on each possible image of each possible patient. Therefore it would be wise to let MI-ES find a *set* of solutions based on an optimal partition of IVUS images. Here a methodology is presented which does dynamic fitness based partitioning of the data during the MI-ES parameter optimization procedure. As a first step we applied this method to a challenging artificial test case which demonstrates the feasibility of our approach.

1 Introduction

IntraVascular UltraSound (IVUS) is a technique used to get real-time high resolution tomographic images from the inside of coronary vessels and other arteries. To gain insight into the status of an arterial segment a so-called catheter pullback sequence is carried out. An example of an IVUS image with several detected features can be seen in Figure 1.

IVUS images are difficult to interpret, which causes manual segmentation to be highly sensitive to intra- and inter-observer variability. In addition, manual segmentation of the large number of IVUS images per patient is very time consuming. Therefore an automatic multi-agent image interpretation system was developed. However, feature detectors in this system consist of a large number of parameters that are hard to optimize, and there are continuous as well as different types of discrete parameters involved. Moreover, these parameters are subject to change when something changes in the image acquisition process.

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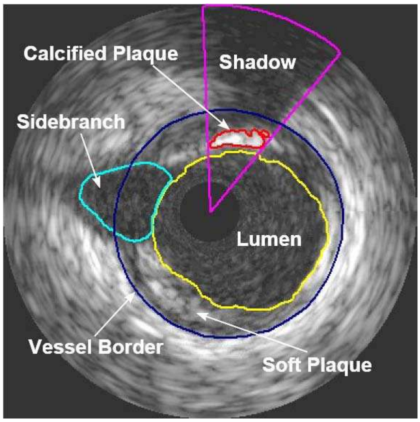

Fig. 1. An IntraVascular UltraSound (IVUS) image with detected features. The black circle in the middle is where the ultrasound imaging device (catheter) was located. The dark area surrounding the catheter is called the *lumen*, which is the part of the artery where the blood flows. Above the catheter *calcified plaque* is detected which blocks the ultrasound signal causing a dark *shadow*. Between the inside border of the vessel and the lumen there is some soft plaque, which does not block the ultrasound signal. The dark area left of the catheter is a sidebranch.

In [1,5] we compared the ability of Mixed-Integer Evolution Strategies (MI-ES) and standard Evolution Strategies (ES) to find optimal parameter settings for the detection of the lumen boundary in IntraVascular UltraSound (IVUS) images. Mixed-integer Evolution Strategies (MI-ES) are a special type of evolutionary strategy that can handle mixed-integer parameters (continuous, ordinal discrete, and nominal discrete) by using different mutation operators for the different types of parameters. Our results showed that the parameter solutions evolved by our MI-ES and ES algorithms were better than the default parameter solutions currently used, but also demonstrated that different sets of images require different parameter solutions for an optimal lumen segmentation.

Because of the complexity and variability of IVUS images, different parameters settings are needed for different image segmentation contexts. An ideal solution would be to classify IVUS images into different image segmentation contexts and optimize parameters for each context separately. Unfortunately, we do not know the number of IVUS image segmentation contexts as well as their characteristics. Additionally, unlike in the case of data points in a metric space, we have no natural distance measure [3] to cluster IVUS images into groups that need similar parameter settings for an optimal segmentation result. Only their degree of belonging to a partition, characterized by a particular set of parameters, can be measured by means of a training error for that image.

A possible approach for this kind of multi-level optimization problem could be cooperative coevolution (e.g., see [6,7]) in which we evolve both a set of parameter solutions and sets of images at the same time. However, this approach