# On Chip Implementation of a Pixel-Parallel Approach for Retinal Vessel Tree Extraction

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***Abstract*— Retinal vessel tree extraction from angiography images play an important role not only in the medical domain, but also in biometric identification applications. From the image processing point of view, a lot of algorithms and strategies have been developed to deal with this topic. Although reliable results have been obtained, the main disadvantage in most of these proposals is still the high computation effort required.**

**In this paper, a methodology to extract the retinal vessel tree has been developed, specially defined in terms of fine grain SIMD processing with the purpose of improving the computation time. The proposal has been implemented on the SIMD processor array chip SCAMP-3. The execution times for the main modules of the proposed algorithm have been included to show its capability.**

## I. Introduction

Currently, the computation of accurate geometric models of anatomic structures from medical images, like the retinal vessel tree, has become increasingly important in both authentication systems [1] and medical applications [2]. Although a lot of research effort has focused on developing algorithms and strategies for the retinal vessel extraction [3], less attention has been paid to the improvement of the computation time.

In this sense, the vessel extraction algorithm proposed in [4] intended to improve the execution time by means of developing all the steps under the Cellular Neural Network (CNN) [5] paradigm. This methodology finds the exterior of the vessels using an active contour technique, the so-called Pixel Level Snakes (PLS) [6]. Fitting the interior of the vessels has been the most usual approach to tackle with retinal vessel extraction [7], [8]. Nevertheless, the main disadvantage of these approaches is that they provide a limited control of the evolution process due to the tubular structures. Moreover, as it has been shown in [7], complex rules should be defined to avoid the contour flowing outside the vessel, whereas the initialisation is also more complex. Our proposal is based on fitting the exterior of the vessels and contour evolution is then controlled in an easy way. The initialisation stage is also clearly easier, specially in an automatic process, since there is a larger proportion of background pixels. PLS have been implemented on hardware architectures with capabilities of single instruction multiple data (SIMD) processing, like the CNN-based chips ACE4K (under the ACE-BOX computing infrastructure [9]) as well as the focal plane processor array SCAMP-3 vision system [10], [11].

Although reliable results have been obtained in [4], some of the CNN-based steps for the estimation of the guiding information and the initial conditions for PLS, have been developed by means of non linear templates which prevents their implementation in the generation of current chips, like those of either the ACEx family or the SCAMP-3.

In this paper, the original proposal addressed in [4] has been redefined in terms of local dynamic convolutions and morphological ”hit and miss” operations together with arithmetic and logical operations to be implemented and tested in a fine grain SIMD processor array, particularly the SCAMP-3 chip. The SCAMP-3 vision system executes a sequence of simple array instructions, like addition, inversion, one-neighbour access, operating in a pixel-parallel fashion on 128x128 arrays, at a rate of 1.25 MOPS per pixel.

The paper is structured as follows: in *Section II* the PLS performance is briefly described, *Section III* the proposed algorithm is explained, in *Section IV* the main results obtained with the SCAMP system are shown, and, finally in *Section V* the main conclusions are discussed.

## II. Pixel Level Snakes (PLS)

Pixel Level Snakes (PLS) are a massively parallel active contour technique inspired by the energy-based deformable models. The inputs consist of a binary image containing the initial contours and a multi-bit image containing the guiding information, called external potential image, which guides the PLS evolution.

PLS contours evolve towards local minimal distance curves, based on a metric defined as a function of the features of interest. PLS algorithm operates along the four cardinal directions performing the evolution as a pixel-by-pixel shift (activation and deactivation of pixels in a binary image). The goal after each cycle (four iterations, one for each cardinal direction) is to obtain a new contour slightly shifted in order to be closer to the boundaries of interest. Like in conventional active contours, the evolution is controlled by means of the internal, the external and the balloon potentials. The internal potential controls the smoothing effect of the contour giving more robustness to the model against noise. The external potential guides PLS towards the boundaries of interest and it should be defined in such a way that the boundaries of