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Segmentation of elongated objects using attribute profiles and area stability: Application to melanocyte segmentation in engineered skin ☆

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ABSTRACT

In this paper, a method to segment elongated objects is proposed. It is based on attribute profiles and area stability. Images are represented as component trees using a threshold decomposition. Then, some attributes are computed on each node of the tree. Finally, the attribute profile is analyzed to identify important events useful for segmentation tasks. In this work, a new attribute, combining geodesic elongation and area stability is defined. This methodology is successfully applied to the segmentation of cells in multiphoton fluorescence microscopy images of engineered skin. Quantitative results are provided, demonstrating the performance and robustness of the new attribute. A comparison with MSER is also given.

1. Introduction

Filtering techniques, aiming at removing noise while preserving as much as possible the desired information, are often essential prior to segmentation. Mathematical morphology [15,25] is a theory of non-linear operators based on a set approach in order to study the objects morphology. Classically, it uses structuring elements. It has been shown that adaptive approaches can lead to important improvements [10,12,22,23,1].

In this paper, we propose a method to segment elongated cells (melanocytes) in multiphoton fluorescence microscopy images of engineered skin. Segmenting these images with standard methods fails since melanocytes are low contrasted and noisy. Moreover, it is proven that including shape prior knowledge improves the segmentation results.

The proposed method is based on the analysis of the attribute profile over the threshold decomposition of an image. We define a new attribute, called area-stable elongation, that combines the geodesic elongation and the area stability. In our experiments, we analyze important events in the evolution of this attribute and we show its efficiency in segmenting elongated objects while filtering out noisy structures.

This paper is organized as follows. Section 2 reviews related work in the state of the art. Section 3 presents the threshold decomposition, the attribute profile and introduces the new area-stable elongation attribute. Section 4 illustrates an application segmenting elongated cells in fluorescence multiphoton microscopy images of engineered skin. Finally, Section 5 concludes the paper.

2. Related work

Jones [6] proposed connected filters using attributes signatures, *i.e.* the evolution of an attribute on the component tree. He has successfully applied his method to the segmentation of wood micrographs. Pesaresi and Benediktsson [21] introduced morphological profiles using the derivative of the residues from opening/closing by reconstruction. Their method is well suited for images with low contrast and low resolution. However, the maximal residue may not be the best segmentation choice. Moreover, the computational cost increases when processing large and homogeneous images. Beucher [2] proposed the analysis of the residue evolution through successive morphological operations. This evolution over each pixel of the image leads to interesting transformations such as ultimate openings and quasi-distance functions. More recently, Ouzounis et al. [20] proposed differential area profiles for efficient point-based multiscale feature extraction in pattern analysis and image segmentation.

Maximally stable extremal regions (MSER), proposed by Matas et al. [14], is a well-known region detector. MSER are invariant to affine transformations of both intensity and image coordinates. They have a high repeatability and can be run in linear time with

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respect to the number of pixels in the image (5 Mpix/s using a max-tree implementation [18]. However, the parameter selection remains its major drawback. Even when default parameters perform well in many applications, some heuristics need to be applied in order to yield appropriate regions. Moreover, MSER favors round regions, as proved by Kimmel et al. [7], making it unsuitable to detect irregular shapes such as elongated objects.

Forssen and Lowe [5] computed SIFT descriptors on the MSER shape in order to characterize each region of the image. This approach is proven to be robust to illumination changes and nearby occlusions. They also proposed a pyramidal searching to reach scale invariability. The authors also suggested the use of MSER for image segmentation. Forssen [4] extended the MSER concept to color images and Litman et al. [11] defined stable volumetric features in deformable shapes.

This paper is an extended version of Serna and Marcotegui [24] work. In that framework, the attribute profile is built over increasing quasi-flat zones and three application are presented: image segmentation, adaptive mathematical morphology and feature extraction. In this paper, we extend the idea of analyzing the attribute profile over the threshold decomposition of an image. Additionally, we define an attribute profile based on a new attribute, called area-stable elongation, to segment elongated objects.

3. Methodology

3.1. Threshold decomposition and attribute profile

A binary attribute can be extended to gray-scale through threshold decomposition [27,13]. Let I be a digital gray-scale image $I : D \rightarrow V$, with $D \subset Z^2$ the image domain and $V = [0, \ldots, R]$ the set of gray levels. A decomposition of I can be obtained considering successive thresholds $T_t(I) = \{p \in D | I(p) > t\}$ for $t = [0, \ldots, R-1]$. Since this decomposition satisfies the inclusion property $T_t(I) \subseteq T_{t-1}(I), \forall t \in [1, \ldots, R-1]$, it is possible to build a tree, called the component tree, with these level sets $T_t(I)$. Each branch of the tree represents the evolution of a single connected component (CC) X_t. An attribute profile is the evolution of an attribute on a branch of the tree.

Fig. 1 illustrates the threshold decomposition in the 1D case, its component tree and attribute (width) profiles for the two maxima

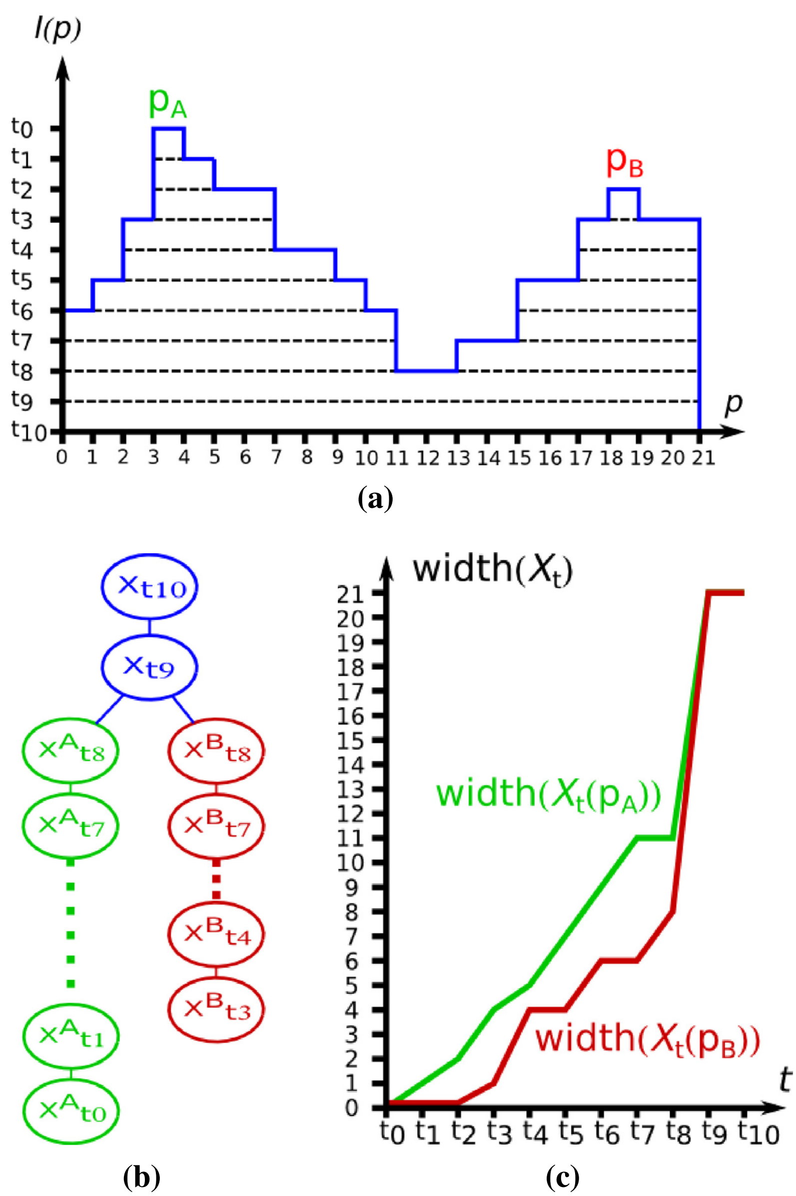

Fig. 1. 1D threshold decomposition (a), component tree (b), and attribute profile (c).

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