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An Image Segmentation Procedure based on the Superposition Principle of Quantum Mechanics

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Abstract

In this paper we propose a procedural approach to the problem of image segmentation. This procedural approach may be parameterized with optimized values for a specific type of data. It uses an algorithm which is inspired by the superposition principle of Quantum Mechanics, in the sense that each particular pixel has a certain probability of being of a certain type (boundary, interior, exterior or noise) and only when an observation is made, by means of choosing a designated threshold value, it gets a concrete state. The procedure is applied to a particular example of vessels network and we determine its maximum length dividing the total area by an average vessel thickness.

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Keywords: Image segmentation; superposition principle; total length of a networkwith average constant thickness;

1. Introduction

The problem of image segmentation is an important problem in most of the current research fields of science and technology. It has even more importance in almost all fields involving medical applications. It is thus not surprising that we can find a huge amount of software that perform such kind of data processing [1]. However, it seems that there is still space for the development of simple and open procedural routines to perform such operations on images. Indeed, most commercial software applications are closed to the user and there is not an effective control of all parameters by the user. In most cases the user is limited to a blind trial and error experiment on the threshold values

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that are provided by the system. The purpose of this work is to provide a simple and open procedure that allows a reasonable number of parameters that can be controlled and understood by the user. In this way, with a very simple implementation, and understanding the meaning of each one of the controls that are involved in the model, as well as the way in which it is organized, the user can explore its capabilities to the maximum of its optimization and thus obtain results that are the best results possible for their purpose. The overall procedure that we are proposing may be summarised as follows.

Procedure: Superposition principle applied to image segmentation

1 – Read the image and map it into a range of four colors, encoded as: 1=exterior; 2=interior; 3=boundary; 4=noise;

2 - Analyze the image and determine the specified regions;

3 - Scale, map it into 4 colors, and rescale (the topological and geometrical properties should be independent from scale; this gives a good measure of how probable it is that a pixel belongs to each one of the specified regions);

4 - Count the number of occurrences of each one of the four regions on each pixel as scale varies;

5 - Define probability functions to determined how likely it is that a given pixel belongs to a certain region;

6- Combine the superposition map into one observation by specifying the region of interest;

7 - Define a threshold value and extract the region.

Nomenclature

Region 1	exterior
Region 2	interior
Region 3	boundary
Region 4	noise

This simple process can be applied to any image in any format or colormap. In relies on the mathematical notion of region in the plane. Formally, a region on the complex plane is the topological closure of the interior of any subset of the plane. This means that it has a well-defined boundary which separates the interior and the exterior. In practice we are only interested in obtaining the interior of a region of interest. However, the concept of boundary, as well as the concept of noise (since this is a common feature in most images obtained from medical application) reveals themselves as a useful intermediate notion to understand the overall procedure which is proposed in this paper. The key idea uses the fact that it is easy to scale and rescale an image, in terms of resolution, and that the interior and exterior points are in general stable to such scaling while the boundary and noisy points are in general unstable under such transformation. This means that when performing a series of scaling and rescaling (for example scale the original image to half of the resolution and then rescaling it to the double of the resolution, which gives an image of the same size but with possibly different values for some of its points) the measure of how stable a given point has stayed with respect to a certain region, gives a good measure of how likely it is of being in that region on the original picture.

2. The overall procedure

In this section we give an example of an image being processed and the output images that are created along the way, when following the steps 1 to 7 supra described. The image is simply an example and we have performed a huge battery of experiments in order kind of images to assert the adequacy of the proposed parameters. In our opinion, these parameters are the ones that are best adjusted to a general and wide range of pictures. This picture in particular was kindly provided by Barbara Klotz (from the University Medical Center Utrecht, Netherlands) and it shows a network of vessels of which we desire to compute the total length.