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Image filtering using morphological amoebas ☆

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Abstract

This paper presents morphological operators with non-fixed shape kernels, or amoebas, which take into account the image contour variations to adapt their shape. Experiments on grayscale and color images demonstrate that these novel filters outperform classical morphological operations with a fixed, space-invariant structuring element for noise reduction applications. Tests on synthetic 3D images are then performed to show the high noise-reduction capacity of amoeba-based filters.

Keywords: Anisotropic filters; Noise reduction; Morphological filters; Color filters; 3D image processing

1. Introduction

Noise is possibly the most annoying problem in the field of image processing. There are two ways to work around it: either design particularly robust algorithms that can work in noisy environments, or try to eliminate the noise in a first step while losing as little relevant information as possible and consequently use a normally robust algorithm Fig. 1.

There are of course many algorithms that aim at reducing the amount of noise in images. Most are quite effective but also often remove thin elements such as canals or peninsulas. Even worse, they can displace the contours and thus create additional problems in a segmentation application.

In mathematical morphology, we often couple one of these noise-reduction filters to a reconstruction filter that attempts to reconstruct only relevant information, such as contours, and not noise. However, a faithful reconstruction can be problematic when the contour itself is corrupted by noise, as seen in Fig. 1. This can cause great problems in some applications which rely heavily on clean contour surfaces, such as 3D visualization, so a novel approach was proposed: morphological amoebas.

An amoeba (here *Amoeba proteus*) is a genus of protozoa that moves by projecting pseudopods and is a well-known representative unicellular organism. They are found in sluggish waters all over the world, both fresh and salt, as well as in soils and as parasites. They now begin a new life in the field of image processing.

2. Amoebas: dynamic structuring elements

2.1. Principle

2.1.1. Classic filter kernel

Formally at least, classic filters work on a fixed-size sliding window, be they morphological operators (erosion, dilation) or convolution filters, such as the diffusion by a

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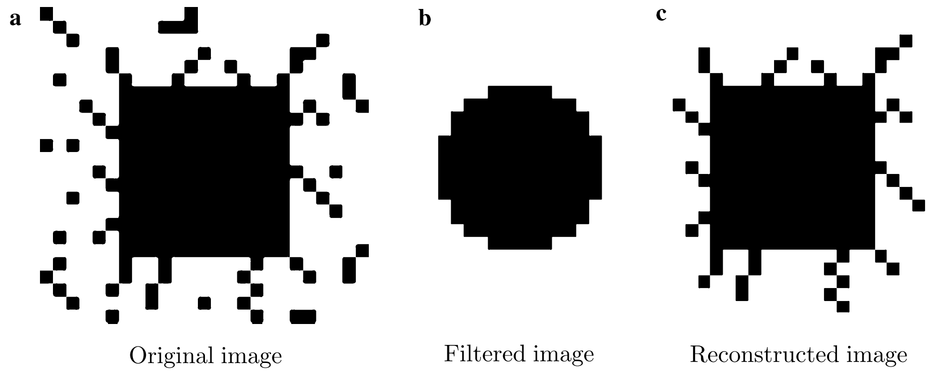

Fig. 1. Classic noise filtering (b) removes much contour information. Reconstruction (c) finds not only the contours, but also all the noise connected to the object.

Gaussian. If the shape of that window does not adapt itself to the content of the image (see Fig. 2), the results deteriorate. For instance, an isotropic Gaussian diffusion smooths the contours when its kernel steps over a strong gradient area.

2.1.2. Amoeba filter kernel

Having made this observation, Perona and Malik [1] (and others after them) have developed anisotropic filters that inhibit diffusion through strong gradients. Most early work on non-fixed shape structuring elements, such as [11] and [7] were restricted either in the types of operations performed (openings and closings) or in the type of images upon which they were to be used.

We were inspired by these examples to define a more general framework to develop filters, either morphological or not, whose kernels adapt to the content of the image in order to keep a certain homogeneity inside each structuring element (see Fig. 3) while at the same time keeping their size in check. Tomasi and Manduchi have described in [5] the coupling of a geometric distance between pixels with a distance between their values, which offers remarkable properties for our intended use.

The interest of this approach, compared to the one based on partial differential equations, is that it does not depart greatly from what we use in mathematical morphology, and therefore most of our algorithms can be made to use amoebas with little additional work. Most of the underlying theoretical groundwork for the morphological approach has been described by Jean Serra in his study [2] of structuring functions, although until now it has seen little practical use.

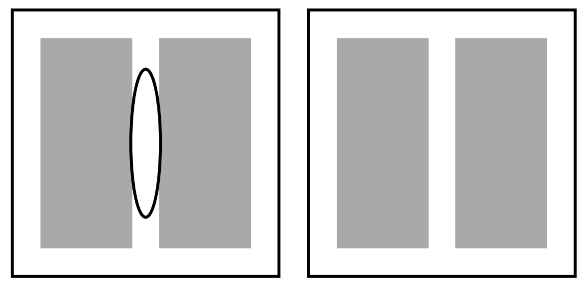

Fig. 3. Closing of an image by an amoeba. The amoeba does not cross the contour and as such preserves even the small canals.

The shape of the amoeba must be computed for each pixel around which it is centered. Fig. 4 shows the shape of an amoeba depending on the position of its center. Note that in flat areas such as the center of the disc, or the background, the amoeba is maximally stretched, while it is reluctant to cross contour lines.

When an amoeba has been defined, most morphological operators and many other types of filters can be used on it: median, mean, rank filters, erosion, dilation, opening, closing, even more complex algorithms such as reconstruction filters, levelings, floodings, etc.

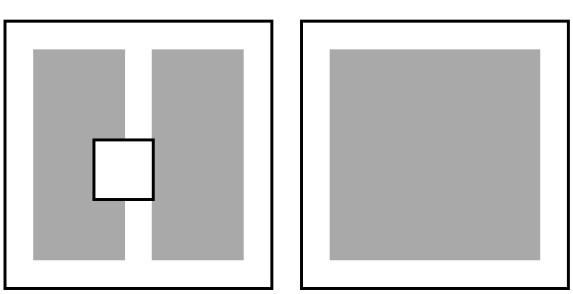

Fig. 2. Closing of an image by a large structuring element. The structuring element does not adapt its shape and merges two distinct objects.

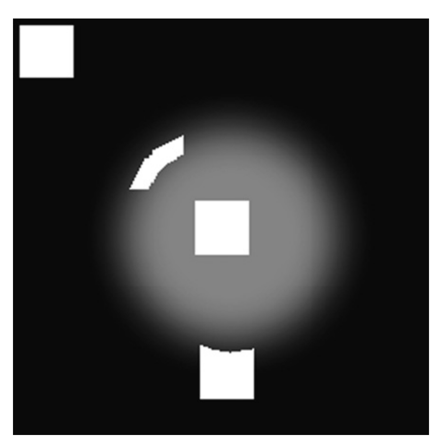

Fig. 4. Shape of an amoeba at various positions on an image.