ADAPTIVE MORPHOLOGY APPLIED TO GRAY LEVEL OBJECT TRANSFORMATION

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ABSTRACT

In this paper, we introduce a new approach to compute a directional transformation of gray-tone objects. The method is based on the definition of elementary forces exerted between the pixels. The dilation and the erosion are then obtained respectively by increasing and decreasing the membership function of the pixel according to the resultant force intensity. In order to emphasize the anisotropic effect of this force, we introduce a penalization function depending on the angular dispersion of the resultants. The effects of adaptive dilation and erosion are illustrated on both synthesized and real objects.

1 INTRODUCTION

Serra has introduced mathematical morphology techniques applied to gray-tone functions (and images) such as erosion or dilation [4]. As these techniques are based on the use of a pre-defined structuring element, the obtained operators do not depend on the overall shape of the object. Our aim is, conversely, to transform objects in preferential directions. For example a dilation might stretch the object along its principal axis without necessarily thickening it and the erosion might thin down the object without necessarily shortening it.

Some techniques were proposed to obtain directional dilation of objects taking into account their morphological properties [5]. Gleason and Tobin [1] proposed an approach based on gravitational forces to dilate and then to merge disconnected objects in a binary image.

In [2] and [3], we introduced an electrostatic formulation leading to an isotropic transformation of objects. This formulation was developed in the case of object dilation in a binary image. Here, we present the extension to the dilation and the erosion of objects in a gray level image.

In this paper, we present a technique which aims to modify the gray level of pixels belonging to an object boundary according to forces exerted by the neighboring pixels. The resulting force exerted on a pixel depends on the local shape of the object. In order to reinforce the adaptive effect, a penalization function is introduced. This penalization is based on the orientation dispersion of resultant forces exerted on the studied pixel and its neighbors.

2 ANISOTROPIC DILATION

2.1 Interaction forces

Let us consider a gray tone image where pixels belonging to an object are darker than background. Then, the opposite of the gray level can be considered as a membership function.

Our technique is based on the definition of elementary forces exerted between the pixels depending on the spectral (gray level) and the spatial distance.

We propose to consider each pixel as a particle and to introduce an interaction force between a given pixel and its neighbors.

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The morphological operations described in this paper are considered through their action on objects, then the dilation will result in the drop of the gray level of pixels.

Let us notice that the dilation (erosion) of dark objects can be seen as a morphological erosion (dilation) according to the classical definition.

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Figure 1: Forces exerted by darker pixels ; 3x3 sized window

Let us consider a given pixel i and its neighborhood defined by a n² sized window V_i.
This window can be viewed as the structuring element of our operators. The difference is that the choice of n can be...
balanced by the tuning of other parameters as we will see in 2.3.

As we want to dilate dark objects, only the darker pixels can exert a force on the studied pixel (Figure 1). The force applied by a pixel \( j \) on a pixel \( i \) is defined by the product of a decreasing function \( \Psi \) of the distance (spatial information) and an increasing function \( \Gamma \) of the gray level difference (spectral information):

\[
F_{ji} = \Psi(d_{ij}^2) \cdot \Gamma\left(\max(I_i - I_j; 0)\right) \cdot u_{ji}
\]

(1)

where \( I_i \) and \( I_j \) are respectively the gray level of \( i \) and \( j \), \( d_{ij} \) is the Euclidian distance between both pixels and \( u_{ji} \) is the unit vector oriented from \( j \) to \( i \).

The use of the function \( \Psi \) permits to control the dependence on the distance between the considered pixels. As a result, we can obtain different dilation effects. In [2], we introduce an electrostatic analogy with:

\[
\alpha = \frac{\Psi(d_{ij}^2)}{d_{ij}^2}
\]

(2)

where \( \alpha \) is a parameter depending on the dielectric permittivity of the environment. However we can implement various distance functions such as:

\[
\Psi(d_{ij}^2) = 1 - e^{-\frac{2\alpha^2}{d_{ij}^2}}
\]

(3)

Finally, the force exerted by a pixel \( j \) on a pixel \( i \) is defined by:

\[
F_{ji} = \left(1 - e^{-\frac{2\alpha^2}{d_{ij}^2}}\right) \cdot \max(I_i - I_j; 0) \cdot u_{ji}
\]

(4)

In (4), the influence of the spectral distance depends on the parameter \( \beta \). Experimentally, the most effective value of \( \beta \) is 0.5.

The resultant force applied on the pixel \( i \) is:

\[
F_i = \sum_{j \in W_i} F_{ji}
\]

(5)

As a consequence, the intensity of the resultant is high if the pixel \( i \) is near to a set of darker pixels, i.e. a set of pixels which belongs to an object with a higher membership value.

### 2.2 Penalization of the resultant force

As explained in part 1, the aim of the dilation is to stretch objects along their principal orientation. As we want to obtain a preferential dilation of the extremities, we introduce a penalization of the force modulus taking into account the dispersion of the resultant orientations in a window \( W_i \) defined around the current pixel \( i \).

We note:

\[
\overline{\Delta \theta}_j = \frac{2}{n(n-1)} \sum_{j' \in W_j} \Delta \theta_{ji'}
\]

(6)

where \( \Delta \theta_{ji'} \) is the difference between the directions of the resultants exerted on \( j \) and \( j' \). \( \overline{\Delta \theta}_j \) measures the angular dispersion in the window surrounding the pixel \( i \).

Then, we introduce a penalization coefficient of the force exerted on \( i \):

\[
p(F_i) = \frac{\gamma}{\gamma + \lambda \overline{\Delta \theta}_i}
\]

(7)

where \( \gamma, \lambda \) are parameters. \( p(F_i) \) tends to 0 when the resultants are collinear (i.e. along the side of an object) and increases when the value of \( \overline{\Delta \theta}_i \) is high (Figure 2).

An illustration of the advantage of the penalization described above is shown in Figure 3. Figure 3a shows a synthesized object and the corresponding result of \( p(F_i) \) is presented in Figure 3b through a gray level image. Values of \( p(F_i) \) are higher near the extremities of the object leading to a preferential dilation of the object along its principal axis.

![Figure 2: Penalization of the resultant](image)

![Figure 3: a) synthesized object, b) corresponding penalization](image)

### 2.3 Dilation of gray level objects

The dilation is computed iteratively using (4), (5) and (7):

\[
I_i^{t+1} = I_i^t \cdot \left[ F_i \cdot p(F_i) \right]
\]

(8)
Figure 4 a) and c) show the results obtained by dilating the object presented Figure 3a respectively with n = 3 and n=11 (5 iterations). The results appear to be very similar because of the influence of the penalization parameter $\lambda$. The advantage of our directional dilation is more perceptible through the results obtained on synthesized objects shown Figure 5.

![Figure 4](image.png)

Figure 4: a) results obtained by dilating the object of Fig3, n=3, $\lambda=1$, $\gamma=10$, c) same method with n=11, $\lambda=0.5$, $\gamma=10$, b) d) representation of the obtained dilations by subtracting the original image.

![Figure 5](image.png)

Figure 5: a), c) synthesized images, b), d) adaptive dilation of a) and c)

3 ANISOTROPIC EROSION

The principle of the method is quite similar to the principle describe above for the dilation. The computation of the force is similar but as the aim is to erode the pixels which are not “dilatable”, the penalization used is $1-p(F_i)$. Then the erosion increases the gray level of pixels belonging to dark objects: The directional erosion leads to thin the objects down. As the force is exerted by darker pixels, the resultant becomes negligible when the object is already thin.

Then, the erosion acts as a skeletonization and underlines the real structure of the objects. Figure 6 shows on An example of an erosion of an image extracted from a manuscript is reported in Figure 6. The use of a classical erosion technique (figure 6b) leads to a blurred image whereas the use of the directional erosion leads to a better image understanding by pointing out the structures of the letters.

![Figure 6](image.png)

Figure 6: a), b) original image of a manuscript and an extract. c) classical erosion result (3x3 structuring element). d) directional erosion based on a 3x3 sized window.
In figure 7, we illustrate once again the efficiency of the directional erosion applied to image understanding. The original image is a view of Le Louvre front. The classical erosion leads to a blurred image while the directional erosion points out the details of the front.

![Figure 7: a) original image, b) classical erosion result (3x3 structuring element), c) adaptive erosion.](image)

4 CONCLUSION

We propose a new approach to compute a directional transformation of gray-tone objects taking into account their main morphological characteristics. The originality of our method is to compute an adaptive dilation or erosion by introducing interaction forces between the image pixels. The dispersion of resultant orientations in a given window surrounding the studied pixel allows to obtain preferential dilation of the extremities and preferential erosion along the principal axis of the object.

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