MAMMOGRAPHY SEGMENTATION BASED ON VISCOUS FLOODING SIMULATION

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Abstract. In the setting of the automatic analysis of mammography images, the detection of opacities of the breast is a complex well-known problem whose feasibility remains to prove again. We present in this article a technique of segmentation in order to detect the microcalcifications in clinical mammograms while achieving a more effective algorithm.The morphological approach to mammography segmentation is based on the watershed transform. It is a very powerful tool, which presents many advantages: it is not parametric, computationally efficient... However, in comparison with energy-based methods as active contours, it does not allow to control the smoothness of the result. In order to introduce geometrical regularization constraints in the morphological segmentation scheme, two options are possible. The first one consists in simulating a viscous flooding for the construction of the watershed. The second one consists in computing the watershed on a smooth relief. In this article, the second alternative is chosen. The relief is modified so that its non-viscous flooding is equivalent to the viscous flooding of the original relief. This choice allows to clearly separate the smooth procedure from the strict watershed computation and thereby to preserve the qualities and speed of the watershed transform.

Key words: Watershed Transform, Viscous Flooding, Mammography's Segmentation.

1. Introduction

Segmentation is one of the most fundamental problems in image analysis. Its goal is to extract the contours of one or several regions of interest in an image.

Depending on the context, a region of interest will be characterized differently using for example its grey level, its contrast, its texture, its shape, its size...

The segmentation method must allow the incorporation of each information needed in order to produce the desired result.

Among all the segmentation methods, the watershed transform is certainly one of the most popular judging by its capability to adapt itself to very different type of images [7, 8]. The image being seen as a topographic relief, the watershed transform involves the simulation of a relief flooding and the computation of watershed lines. The choice of the relief entirely determines the localization of the watershed lines. The big issue is to build the "good" relief using the available a priori knowledge.

Contours generally correspond to crest lines of the gradient norm of the original image. When they are noisy or badly defined, the segmentation must result from a compromise between a complete adherence to the data (and possibly to the noise) and a certain amount of modeling. In a such situation, energy-based methods have an advantage because smoothness terms are incorporated in the model itself [5, 3, 10, 2, 12]. On the contrary, the morphological approach leaves the choice between two different options. The first one is closed to the energy-based approach. It consists in incorporating smoothness terms in the watershed model itself by simulating the behavior of a viscous fluid for computing the watershed [9, 4]. The second solution aims to modify the relief itself. This second option allows to clearly separate two steps: in one hand, the incorporation of the smoothing constraints into the topographic relief itself and in an second hand, the plain watershed. The benefits of the watershed transform (its computation efficiency, its non parametric aspect...) are preserved.

2. The watershed-based segmentation

2.1. Flooding simulation and watershed lines

the watershed transform is a skeleton by influence zone associated to a certain distance: the topographic distance. From a pragmatic point of view, the watershed transform computation involves a flooding simulation and the computation of watershed points. This vision will be needed in this paper. Let us detail it.

The mammography is seen as a topographic relief: the function values are interpreted as altitudes, the regional minima are located at the bottom of the valleys. It is supposed that the contours to be extracted in the image correspond to crest lines of the relief (see figure 1). The topographic relief is progressively flooded by a number of lakes of increasing altitude. If each regional minimum defines a flooding source, different lakes will appear. All over the flooding process, each lake will take the exact shape of the valley. When two lakes of different sources meet, we are on a point of the watershed line. The flooding process is pursued till the relief is entirely flooded [6, 14]

2.2. The morphological closing: a classical pre-processing

The watershed transform allows to segment an image if the contours correspond to crest lines of the flooded relief and if flooding sources are placed inside the regions of interest. For our mammography presented in figure 2. Two flooding sources have been manually placed: one inside and one outside the micro calcification . The relief to be flooded is the morphological gradient of the original image (dilation minus erosion). Note that is this case especially, the flooding of the original image were thinkable.

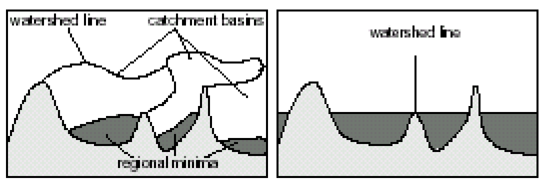

Fig. 1: The topographic analogy: points where two lakes meet define the watershed line.

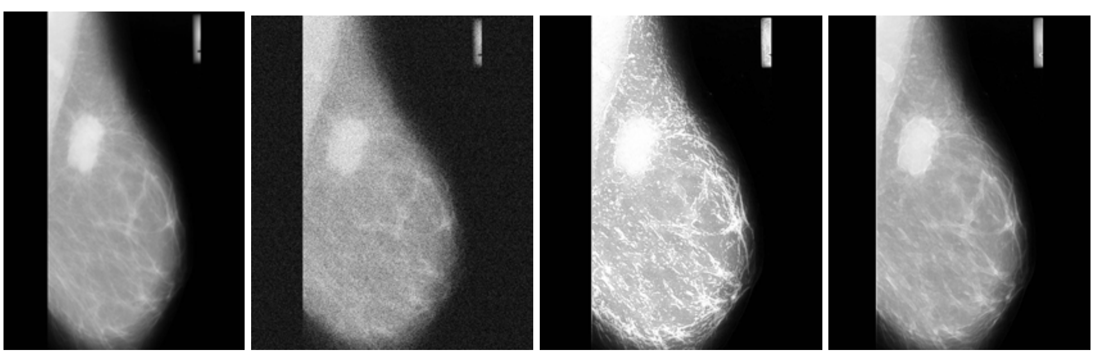

Fig. 2 :From left to right: original image, relief to be flooded (morphological gradient), flooding sources (in gray), watershed line.

Without pre-processing, the watershed line is poorly localized. This was foreseeable: except for experts, the precise localization of the breast contour is quite impossible because of the noise . During the flooding procedure, water leaks between fragment contours and some lakes may meet at wrong places. This phenomenon is quite frequent in the case of noisy data (and especially when gradient images are considered). A classical solution to prevent water leak consists in closing the contours by computing a morphological closing. It is recalled that the morphological closing of a set A using a symmetrical structuring element B is defined by :

$$\varphi(A) = \bigcap_{x \in E} \{B_x \setminus B_x \cap A \neq \{\ \}\}$$

where Bx denotes the structuring element B centered at point x and where E denotes the mammography space. If B is a set, the closing of a function f may be easily defined by closing each section of *f*.

The result obtained in our example and presented in figure 3 illustrates a well known duality: without prefiltering the segmentation is precise but noise sensitive; with prefiltering the segmentation is robust but less precise. Our purpose here is to attempt to gain simultaneously in precision and in robustness.

The solution suggested here and presented in the next section is based on the construction of a more adequate modified relief inspired from the idea of a viscous flooding simulation.

3. Viscous flooding simulation

The aim of this part is to modify the original topographical relief in a such way that the level lines of the non viscous flooding of the modified relief are the same as the level lines of the viscous flooding of the original relief. A relief is decomposed into several elementary cylinders [1]. The case of a single cylinder is firstly treated and then extended to the case of a complex function.

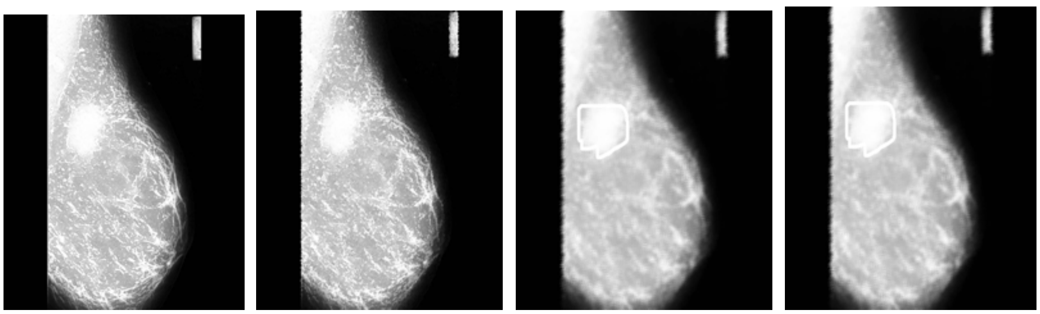

Fig.3 : From left to right : original gradient, closed gradient (closing by a disk of radius $r_0 = 12$)

4. Application to mammography : Case of a unique flooding source

In the case of a unique flooding source, the strategy is very closed to the strategy developed in active contours theory: an "active variety" evolves inside or outside an object till its position coincides with the contour of the object. In our case, the active variety is a viscous fluid slick. A flooding source is placed inside the breast. The simulation of the viscous flooding involves:

1. the computation of the viscous closing : $F_v = \wedge_{t \geq 0} \varphi_{r(t)}(f + t)$
2. the threshold of the closed relief at level h: $S_h = \{x \in E, f_v(x) < h\}$
3. the extraction of the border of the connected subset of S_h containing the marker of the breast.

Two parameters have to be choosen: the flooding level h and the values of the radius r(t) when t varies between 0 and h. Note that this parameters are similar to those classically imposed in active contour models.

The choice of the function r(t) may not be linked to any data or a priori knowledge. In this paper: $r(t) = r_0 e^{-\lambda k}$, where r_0 defines the viscosity under the atmospheric pressure ($r_0 = 12$) and where λ , is a constant (here $\lambda = 0.1$ what guaranties $r(h) \to 0$ when $h \to \infty$ at the scale of the data). This function has been chosen because it is simple but others functions may be imagined. Note that the viscous closing is not invariant by contrast change as it was the case for the morphological closing (r derives from the levels t). This explains the importance of the scale parameter λ .

The last parameter to be fixed is the final level h. In active contour models, . In active contour models, it is fixed by searching a local minimum of the evolution function. In our example, the final level is fixed in the following way: the watershed is firstly computed on the closed gradient (by a disk of radius r_0). It is assumed that the result is closed to the desired contour. h is then fixed as the average of the gray levels of all watershed points.

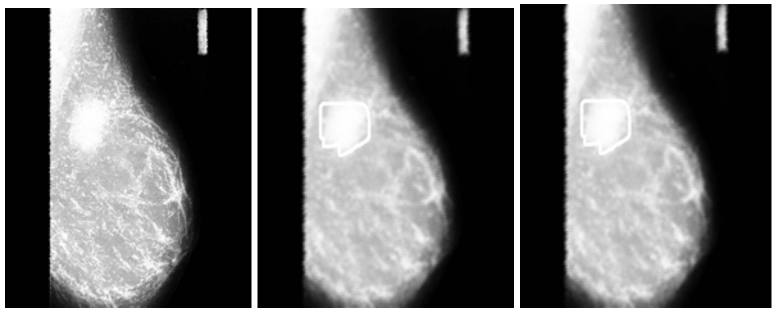

Fig 4. From left to right : Watershed line computed on the original relief, on a closed relief and a relief modified by viscous closing

5. The viscous watershed

If several flooding sources are considered, it is possible to define a kind of viscous watershed by computing the watershed associated to the relief modified by viscous closing. The markers being the same as in figure 2, the segmentation obtained is presented in figure 4 and compared to the segmentation obtained by standard methods. The result is not so smoothed than expected. The reason is the following: two viscous lakes may meet only if they are strongly compressed.

But in that case, the result is not smoothed anymore. Several solutions may be imagined: for example, the flooding process may be stopped before the relief is entirely submerged.

6. Conclusion

This article presents a new segmentation method based on a viscous flooding simulation. The viscosity is introduced by the way of a family of openings of decreasing radius. It is proved that the viscous flooding of a certain relief equals to a standard flooding of a filtered relief: the filtering procedure is called a viscous closing. From a segmentation point of view, the viscosity plays the same role as the rigidity in the active contours: the results obtained by these methods are very similar. Moreover, the treatments being not symmetrical, the definition of a kind of viscous watershed transform is not easy. This question has yet to be solved.

7. References

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