Segmentation of Satellite Image using Geodesic Active Contour

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Abstract-In this paper we present the method of satellites images segmentation. The technique is based on the geodesic actives contours using geometric approach. We shown that a particular case of the classical model of Contours actives or "snakes" is amounts seeking a geodesic curve in Riemann space whose metric one is defined by the contents of the image, i.e to find a curve of minimal length in a certain space. By regarding geodesic active contour as level zero of an explicit function ("level set" approach developed by Osher et Sethian [1]), the search for this geodesic curve induced the solution of an partial derivative equation. So this intrinsic approach does not force initial contour to have same topology as the final curve. It is not either necessary to know the topology of the solution a priori (number of objects to segment). This diagram is applied to a satellite image and the results obtained show the effectiveness of the method suggested.

I. INTRODUCTION

The segmantation is a fundamental subject in the image processing. Several methods were proposed, among which we quote active contours. They were introduced by Kass, Witkin et Terzopoulos in their paper: "Snakes: Active Contour Models" [2]. They are presented in the form of a model for the extraction of visual characteristics in an image like contours of object or the elements of borders In this classical approach, the basic idea is to position near the contour to be detected, a curve which will be the initialization of active contour and successively to deform it until it with the border of the object. The criterion used by Kass and its collaborators corresponds to the minimization of a functional called Energy. Energy "snake " defined in [2] is written as the sum of an internal energy controlling the aspect of the curve *c* and of an external energy still called energy image while attracting the curve *c* towards the object which one seeks the borders. The snake thus defined will not change topology in the course of time. There will remain single curved closed for example and will be unable to detect several objects on an image. Moreover, the definition of energy depends on the curve, this approach making it possible to manage the topological changes. [4]

A particular case of the energy model of the snake called geodesic active contour is equivalent to seek a geodesic curve in a space of Riemann whose metric is induced by the contents of the image [5]. We present the technique of geodesic active contours implemented by the method of ' level set'.

II. GEODESIC ACTIVES CONTOURS

The traditional approach of active contours consists in initializing a contour by a closed curve which we deform by minimizing a functional.

The space of the forms is the whole of the curves parameterized according to:

$$E(C(s)) = \int_{\Omega} \frac{\alpha(s)}{2}\left|\frac{dC}{ds}(s)\right|^2 ds + \int_{\Omega} \frac{\beta(s)}{2}\left|\frac{d^2C}{ds^2}(s)\right|^2 ds - \int_{\Omega} \lambda \left|\nabla I(C(s))\right|^2 ds$$

$$\phi = \left\{ C \,\middle|\, C : \begin{matrix} [0,1] \to R^2 \\ s \mapsto \begin{pmatrix} x(s) \\ y(s) \end{pmatrix} \end{matrix}, C(0) = C(1) \right\}.$$

Let (s) a parameterized plane curve and I the image on which we hope to do the detection of contour, we associate at the curve an energy defined by:

(1)

Where C' and C'' the derivative first and seconds of c along the curve and Ω the area.

The first and second terms are the terms of regularization in elongation and torsion (internal energy of contour) whereas the last term represents the fastener with the data and definite a force of attraction of contour deduced from the gradient of the image. We can also add a force of expansion according to a balloon model, developed by Cohen [6], to be less sensitive to initialization. We solve the problem of detection of contours by seeking a curve C which minimizes E by various methods (elements or finished differences or dynamic programming [7]). It appears that this approach of the Euler-Lagrangian type does not allow the changes of topology of the curve *C*.

This problem is solved in the approach of Caselles [3] and Sethian [8, 9, 10] which introduced a geometrical model of active contours, models founded on the theory of evolution of curves and either on minimization of functional interpreted in term of energy. The curve evolves according to its normal with a speed proportional to its curve balanced by a function related to information of the image. The implicit representation of the curve via an explicit function ("level set" approach) allows solving the problems involved in parameterization. The model is intrinsic and the initial condition does not have necessarily the same topology as the final curve, this approach making it possible to manage the topological changes. So Caselles and al. propose the following model:

$$\frac{\partial u}{\partial t} = g(|\nabla I|)|\nabla u| div(\frac{\nabla u}{|\nabla u|}) + cg(|\nabla I|)|\nabla u|,$$
$$= g(|\nabla I|)(c+k)|\nabla u|,$$

with *c* a positive constant, *k* curve and *g* a function which stops the face on the borders of the object to be segmented. *g* is of the type:

$$g(|\nabla I|) = \frac{1}{1+|\nabla \hat{I}|^p}.$$

Constant *c* must be selected rather large so that the *c*+*k* quantity is of constant sign, which ensures the extraction of contours of no convex form. $\hat{I}$ is the image obtained by convolution of *I* with a Gaussian filter and *p* = 1 or *p* = 2. In the case of the model considered, the " level sets " *c* of *u* evolve according to the equation:

$$C_t = g(|\nabla I|)(c+k)\vec{n}.$$

In [5], Caselles, Kimmel and Sapiro recall that if a planar curve *c* evolves according to the equation:

$$C_t = \beta \overrightarrow{n},$$

$\vec{n}$ indicating the interior unit normal with the curve and β being a given function (one supposes moreover that the parameterization of the curve in *q* is such as for *q* growing, the interior of the curve is on the left (cf figure 1), thus the unit normal interior is defined by : $\vec{n} = \begin{pmatrix} \dfrac{-C_2'}{\sqrt{C_1'^2 + C_2'^2}} \\ \dfrac{C_1'}{\sqrt{C_1'^2 + C_2'^2}} \end{pmatrix}$ and the curve *k* is such as $k = \dfrac{C_2''C_1' - C_1''C_2'}{(C_1'^2 + C_2'^2)^{\frac{3}{2}}}$ and if C is a “level set” of the function *u*, (*u* presumedly negative inside the " level set ", positive outside) then *u* satisfies the partial derivative equation:

$$u_t = \beta |\nabla u|.$$

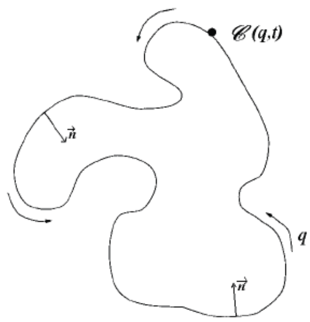


FIG. 1 – Parameterization of the curve C **.**

The term $C_t = k\vec{n}$ corresponds to the equation of heat and has smoothing geometrical properties: this flood ("shortening flow") decreases the total curve as well as the number of passages by zero and the values of maximum and minima of the curve. When the curve is positive, the face is thus "returning", when the curve is negative, the face is "outgoing".

The objection which one can formulate as for this model is on the one hand, the difficulty of the choice of the parameter C, and on the other hand, the lack of robustness of the model when the variations of levels of gray along a contour are contrasted. The model of geodesic active contours introduces by Caselles and al. is abstracted from the component $cg(|\nabla I|)|\nabla u|$ and proposes a more inclined model to attract contour towards the borders of the object considered.

Indeed, Caselles and al. are interested in a particular case of (1) by posing β= 0. They show that this model amount seeking a geodesic curve in a space of Riemann whose metric one is induced by the contents of the image. The approach evolution of curve takes

precedence over the approach minimization of functional interpreted in term of energy.

a) Introduction of geodesics:

If C indicates a curve parameterized in R^2, it is pointed out that the energy which is associated to him in the case of the classical "*snakes*" is given by:

$$E(C) = \alpha\int_0^1 |C'(q)|^2 dq + \beta\int_0^1 |C''(q)|^2 dq - \lambda\int_0^1 |\nabla I(C(q))| dq$$

Posing β= 0 and generalizing the expression of the potential associated with the force with image to a strictly decreasing function $g : [0,+\infty[\to R^+$ such as $\lim_{r\to+\infty} g(r) = 0$ $\lim_{r\to+\infty} g(r) = 0$, *E(C)* is rewritten:

$$E(C) = \alpha\int_0^1 |C'(q)|^2 dq + \lambda\int_0^1 g(|\nabla I(C(q))|)^2 dq$$

let

$$U(C) = -\lambda g(|\nabla I(C(q))|)^2.$$

Applying the principle of Fermat to their model, Caselles and al. show that returns to minimize :

$$\int_0^1 g(|\nabla I(C(q))|)|C'(q)|dq.$$

So caselles and al.. [Case. 93] established equivalence between the minimization of energy of the traditional problem of the "snakes" and seeks it of a geodesic curve in a certain space of Riemann. Let us notice that the Euclidean length of the curve C is given by:

$$L_C = \int_0^1 |C'(q)| dq.$$

By using the normal parameter setting using the X-coordinate curvilinear $\begin{cases} s(q) = \int_0^q |C'(x)| dx \\ ds = |C'(q)| dq \end{cases}$ the length L_C can be rewritten in the form:

$$L = \int_0^{L_C} ds.$$

The length of the curve in Riemann space is given by:

$$L_{R_C} = \int_0^1 g(|\nabla I(C(q))|)|C'(q)|dq,$$

Or

$$L_R = \int_0^{L_{R_C}} g(|\nabla I(C(q))|ds.$$

Caselles and al. [Case. 93] thus introduced a new definition of the length which contains information relating to the image.

a) Curve evolution Equation and " level set" approach:

Caselles and al. establish the Curve evolution Equation C to deform initial contour C(0) = C_0 towards a local minimum of L_{R_C}. (Demonstration in [Cas. 93]). The idea of the demonstration is to build a family of curves $(C(t,q))_{t\geq 0}$, t being a parameter representing time and such as C (0,q) = C (Q). we define the functional $L_{R_C}(t,q) = \int_0^1 g(|\nabla I(C(t,q))|)\left|\frac{\partial C}{\partial q}\right|(t,q)dq$ and we calculate $L'_{R_C}(t)$. We conclude by determining the flood for which decrease $L_{R_C}(t)$ most quickly.

The equation is given by:

$$\frac{\partial C}{\partial t}(t) = g(|\nabla I|)k\vec{n} - (\nabla g(|\nabla I|).\vec{n})\vec{n},$$

with *k* the curve, $\vec{n}$ the interior unit normal and (·) the Euclidean scalar product in R^2. The detection of the object is carried out when the stationary state ($\frac{\partial C}{\partial t}(t)$ = 0) is reached.

The approach " level set " is then integrated into the model. The problem is thus equivalent to find the solution obtained in a stationary state of the equation of following evolution:

$$\begin{aligned}\frac{\partial u}{\partial t} &= |\nabla u| div(g(|\nabla I|)\frac{\nabla u}{|\nabla u|}),\\ &= g(|\nabla I|)|\nabla u| div(\frac{\nabla u}{|\nabla u|} + (\nabla g(|\nabla I|).\nabla u),\\ &= g(|\nabla I|)|\nabla u|k + (\nabla g(|\nabla I|).\nabla u).\end{aligned}$$

III. “LEVEL SET” METHOD:

This method was developed by Stanley Osher and James Sethian in 1988 ([85]). It has since, is the subject of very many developments and applications. The formulation by "level set" is based on the consideration: a curve can be regarded as level 0 of a function of higher size.

Indeed, a face 2D Γ (separating for example two areas) evolves according to its normal with a speed F. This face Γ is regarded as level zero of a function Φ 3D. The idea of this method "level set" is then to deduce the propagation of Γ from the propagation of Φ.

Remark:

In the case of the "snakes", the face at the moment t+ 1 results from the face at the moment t and that thus implies an intrinsic parameterization with the curve. In the technique «level set ", Γ is the intersection of Φ with the plan z = 0, the form of this intersection being able to be unspecified. Fig.2

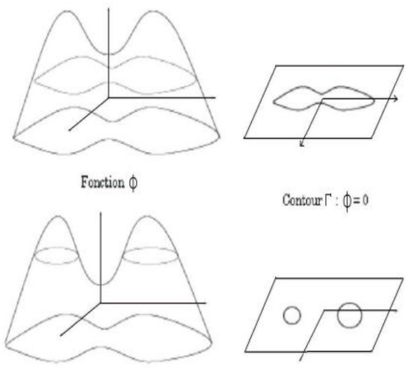


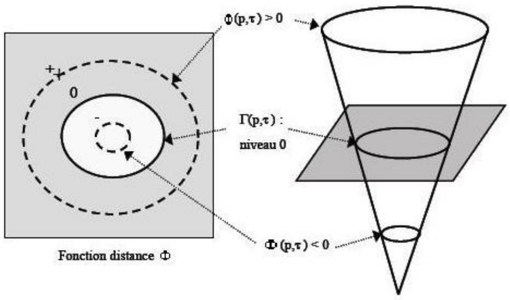
FIG. 2 Representation «level set " of a contour

Calculation of evolution equation:

Let Γ initial contour, closed curve of R^2 and F a function which gives the speed of Γ in the normal direction. The method "level set" consists in regarding Γ as level zero of a function Φ, Φ: $R^2 \to R$ called function "level set" (Osher and Sethian [85] build by using the function distance signed), such as :

$$\begin{cases} \text{si } x \in \Gamma, \Phi(x,t=0)=0, \\ \text{sinon } \Phi(x,t=0)=\pm d, \text{ où } d \text{ est la distance de } x \text{ à } \Gamma, \end{cases}$$

the positive sign (negative) is selected if item x is to the exterior (interior) of Γ. Fig. 3



So we have: $\forall t$,

$$\Phi(\Gamma(t),t)=0.$$

We derive this equation compared to the variable t and we deduce from it the evolution equation satisfied by:

$$\begin{cases} \dfrac{\partial \Phi}{\partial t} + F|\nabla\Phi| = 0 \\ \Phi(x,t=0) \text{ given.} \end{cases}$$

The approach " level set " thus results in solving an partial derivative equation in a space of size higher compared to the original problem. Solved once this partial derivative equation, we rebuild the interface $\Gamma(t)$ at every moment t by taking level zero of the function "level set" Φ (·,t).

IV. IMPLEMENTATION OF GEODESIC ACTIVE CONTOURS WITH THE 'LEVEL SET'' APPROACH

To study the performances of the method of geodesic active contours with the approach of level set for the propagation of the face, we apply it to a satellite image with low resolution.

The image comprises a great quantity of data but generally this image is noisy by undesirable pixels which could modify useful information, therefore it is essential to pass by the stage of pretreatment. We apply to the initial image a median filter used to eliminate useless information. Fig.5

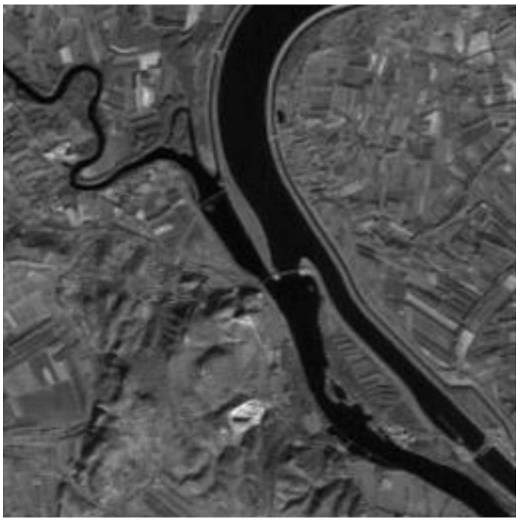


Fig. 5 Median filter

After the operation of filtering, we apply to the image the method of geodesic active contours with Set level described previously with an aim of extracting contour from the various forms located to the image.
The curve C used in our case is a triangle as illustrated on the figure (6).

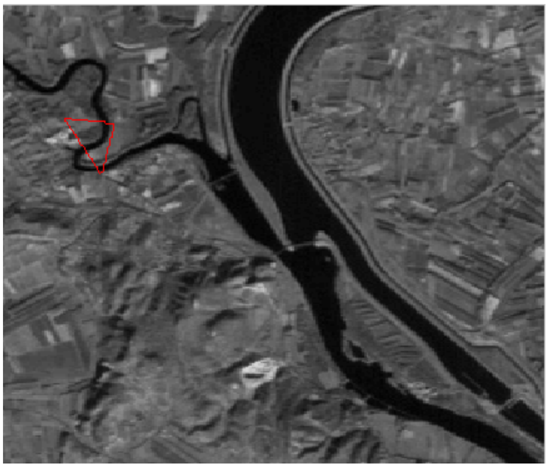


Fig.6. Initialization of the curve

The result is given in figure 7. We notice that all the forms were extracted and that initial contour changed topology.

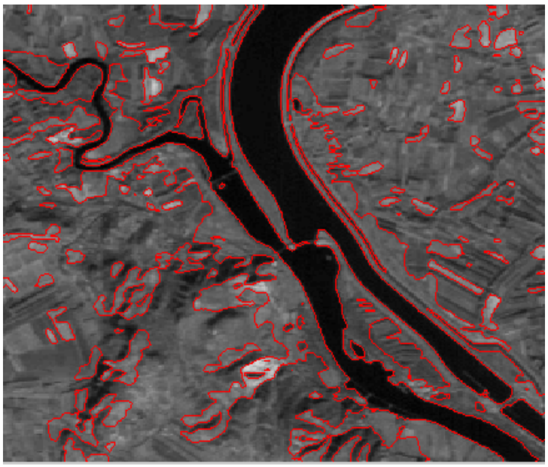


Fig.7 Extraction of the existing forms on the image

V. CONCLUSION

The application of the methods of segmentation of the satellite images remains still a very wide field of research. We presented in this article, one of the techniques of active contour, and more precisely the model of active contour geodesic by the Level-Sets. We tested this method on real images satellite. This model gives very satisfactory and encouraging results, in term of quality of image and execution time

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