Different fusion strategies to detect geographical objects by active contours in multi-temporal SAR images

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Abstract

When a geophysicist has to make a visual interpretation in multi-temporal SAR images, it may be long and repetitive. To avoid this, an automatic object detection using multi-temporal active contours is proposed in this paper. The information brought by the different images can be fused at different levels: either at the data level, the feature level or a level close to the decision level. On two data-sets, both located in French Guyana, two different strategies will be tested depending on the knowledge of the object, whether it is temporally stable or moving.

Keywords: Multi-temporal SAR images, active contour, remote sensing

1 Introduction

Thanks to earth observation satellites such as ERS-1/2 (European Remote Sensing) and now ENVISAT (ENVIronment SATellite), a large number of SAR (Synthetic Aperture Radar) images are now available in many regions. However SAR images are poisoned by the speckle which makes their visual and automatic interpretation difficult. Images from the same repeated orbits can be combined to obtain multi-temporal data sets. Those data sets can be used for an automatic retrieval of stable and/or moving objects (such as savannah's area borders, coast line, ...).

One of the most used routine for object detection is active contours [1] (also known as Snakes). Because of their local calculation, snakes are not well adapted for noisy images and poorly contrasted borders. On the other hand, they present a good trade off between automatic and manual detection, since the snake's initialization is done manually. Applying the snake approach to SAR images requires the use of a specific edge detector such as the ratio of local means [2]. The use of multi-temporal data on a selected area can improve the detections, hence facilitate the work of the end-users.

In this paper different fusion strategies are proposed to detect objects by active contours in multi-temporal SAR images. Depending on the contour type, either moving or not, the strategies will be slightly different.

On one hand when the contour information contained in the different images is redundant, it can be fused to improve the detection of stable spatial objects. On the other hand, the information can be combined to allow a tracking of moving objects in time series.

The fusion can occur at the different steps of the processing chain as illustrated in figure 1. It can be either on the images (data level)or on the ratio of local means image (feature level)for stable objects, or on the positioning of the snakes (close to the decision level) for moving objects.

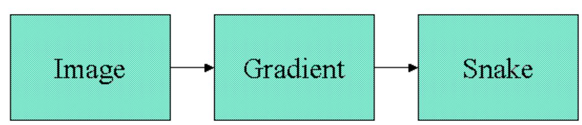

Figure 1: Different steps of the processing and levels where the fusion may occur when using multi-temporal data

2 Data and active contours principles

2.1 SAR multi-temporal data

Two different sets of SAR images are used for the study, both located in French Guyana. All the images are acquired with descending orbits of ERS satellites. For the stable object, a savannah area around Kourou has been chosen (cf. Tab 1). This savannah is only submitted to the seasonal evolution (from dry to humid). For the mov-

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ing object, the selected area is located around Saint Laurent du Maroni (cf. Tab 2). The contours of this area are temporally stable, but a simulated evolution has been created by shifting the different images to obtain a controlled displacement (cf. Tab 3).

Date	Frame	Orbite	Plateforme
03 mai 1992	3501	4177	ERS-1
07 jun 1992	3501	4721	ERS-1
29 nov 1992	3501	7183	ERS-1
14 mar 1993	3501	8686	ERS-1
27 jun 1993	3501	10189	ERS-1
10 oct 1993	3501	11692	ERS-1
14 nov 1993	3501	12193	ERS-1

Table 1: Images of the Kourou data-set

Date	Frame	Orbite	Plateforme
06 nov 1992	3501	4220	ERS-1
10 jun 1992	3501	4721	ERS-1
02 dec 1992	3501	7226	ERS-1
26 mai 1993	3501	9731	ERS-1
30 jun 1993	3501	10232	ERS-1
29 mar 1996	3501	24604	ERS-1
04 jan 1997	3501	8939	ERS-2
15 nov 1997	3501	13448	ERS-2

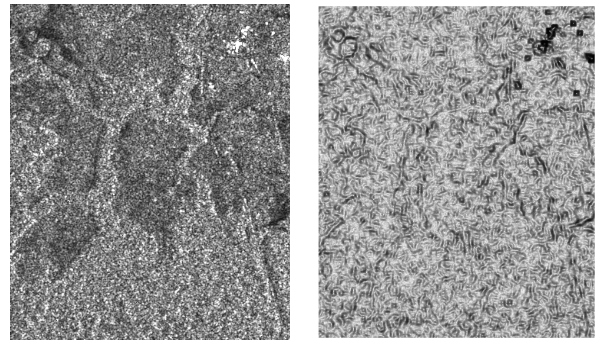
Table 2: Images of the Saint Laurent du Maroni data-set

	X-coordinate Displacement	Y-coordinate Displacement
image 1	+8	+9
image 2	+7	+7
image 3	+5	+5
image 4	+5	0
image 5	—	—
image 6	-4	-1
image 7	-5	-1
image 8	-12	-7

Table 3: Displacement in pixels of the various images toward the "reference" image

2.2 Active contour (snake) principle

The snake positioning is usually driven by internal constraints and external information extracted from the image(s) [1]. In this application, this information is extracted from the SAR images, by using the Constant False Alarm Rate (CFAR) edge detector proposed in [2]. It computes the ratio of local means on both sides of possible edges in different directions and retains the minimum ratio (the strongest contrast) and associated orientation. A result of this first step which provides a "gradient information" is illustrated in 2(b).



(a) Original image

(b) Ratio edge detector output (7x7 window)

Figure 2: Extract of the Kourou data-set, French Guyana, savannah test area

The snake is based on the minimization of an energy function whose terms are the following:

- Continuity: It is an internal constraint that specifies that the location a snake point should make the distance between itself and its neighbors close to the average distance between points,
- Curvature: It is an internal constraint that specifies that a snake point location should minimize the amount of curvature it introduces,
- Gradient: It is an external constraint that specifies that a point of the snake should locate itself in areas where the gradient in the image is large. i.e. the ratio is low for SAR images.

The snake makes a series of local choices at the point level so that an optimum solution can be found at a global level. In this study, the search window of the snake will be a 5x5 window, whether the object is stable or moving.

The performances assessment is done by comparing the results with a reference, carefully drawn by the geophysicist. The distance used in this paper is the chamfer distance proposed in [3] like it was used in [4].

3 Stable objects

Some objects are temporarily stable or move very little compared to the image resolution. For this kind of objects, we can consider that the contours are at the same location on the different images. For this detections two approaches can be used to fuse the multi-temporal information:

- at the data level: fusion of the SAR images to use a unique less noisy SAR image (cf. fig 3)
- at the feature level: fusion of the SAR contour extraction (cf. fig 4)

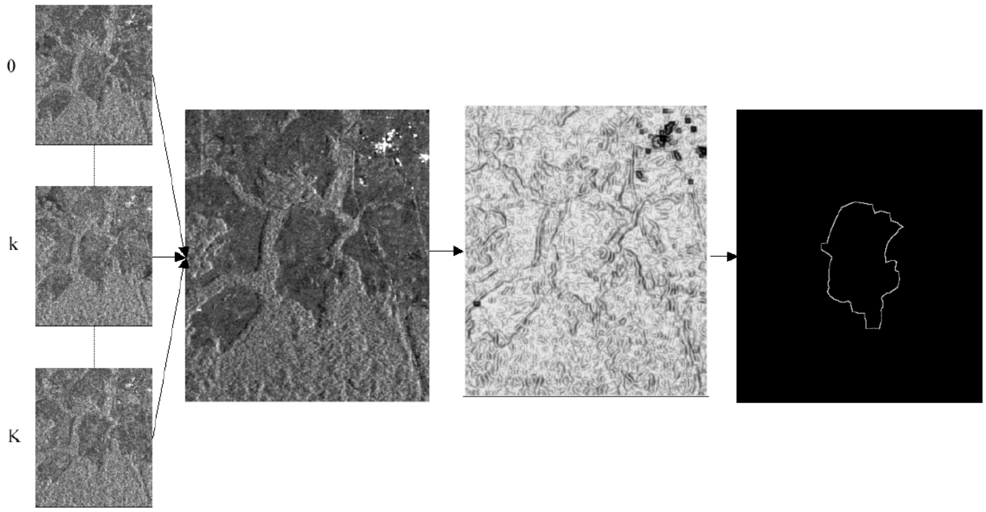


Figure 3: Fusion at the data level

3.1 Fusion at the data level

A mean-image consisting of the temporal average of the data set is calculated. The geophysicist draws a rough initialization on this image. The ratio edge detector is applied on the single mean image. The output of the detector is the input of the snake. Then the snakes improves this initialization to best fit the real contour.

As seen in table 4, making a fusion at the data level improves the detection reliability, when the detection is worsen by a mono-date snake.

3.2 Fusion at the feature level

A slightly different approach consists in calculating the ratio of local means for each image. This gradient measures are composed of the intensities of the contrasts between adjacent regions and the orientation of the strongest contrasts. These two pieces of informations are combined to form a complex number with the contrast strength as magnitude and the orientation as phase. Then these complex numbers are averaged to obtain a "mean" contrast and associated orientation. The stable spatial objects are enhanced by this averaging whereas the false edges are reduced.

The initialization is done on the image which provides the better contrast in the data-set (here image 4). In table 4, we note that making a fusion at the feature level reduces the detection reliability and is even worse than the rough initialization.

4 Moving objects

A different strategy is proposed for moving objects: a ratio of local means is calculated on each image. Then the strategy can either be as simple as a propagation of the result to initialize the following image, or a multi-snake approach dealing with all the K images to position simultaneously K snakes tracking the same object.

	initialization	result
image 1	2.83	2.98
image 2	2.52	2.74
image 3	5.16	5.38
image 4	3.12	3.50
image 5	4.75	4.76
image 6	3.50	3.30
image 7	3.77	3.55
fusion(data level)	4.33	3.75
fusion(feature level)	3.12	4.10

Table 4: Distances between the manually drawn references and the initializations, the snakes results without fusion, and the two fusion results : at data level, and feature level

4.1 Causal evolution

The first approach for moving objects is called "propagation by initialization". The geophysicist provides the first initialization, the resulting snake will initialize the snake of the second image and so on. It can be summarized by the following algorithm:

Algorithm 1 Propagation by initialization

$Snake\_Initialization(image\ 1)$
$Snake\_Calculation(image\ 1)$
for $k = 2$ to K **do**
  $Snake\_Initialisation(image\ k) = Snake\_Result(image\ k-1)$
  $Snake\_Calculation(image\ k)$
end for

The results are reported in table 5:

This method quite natural comes quickly to a limit. If the time between two image acquisitions becomes important, the contour displacement can become greater than the search area of the snake, hence the object is lost.

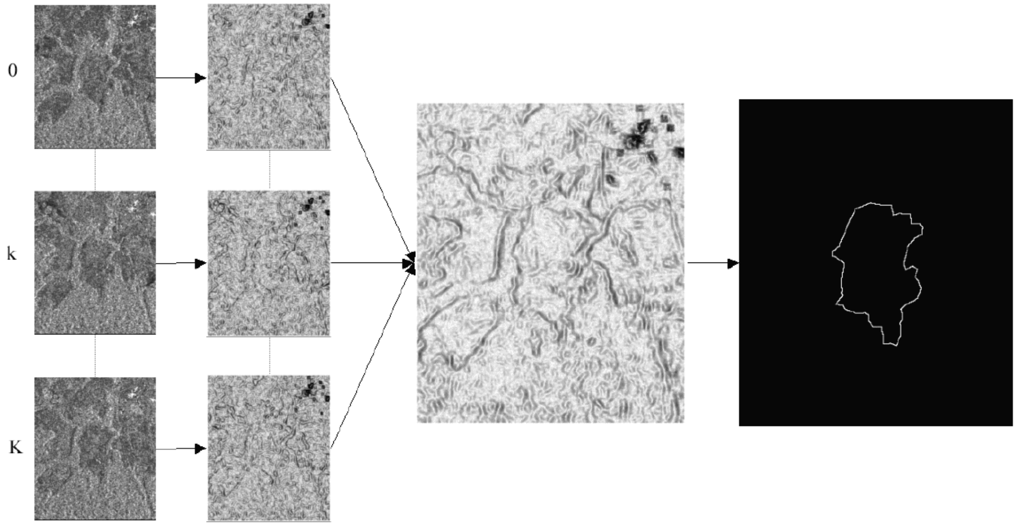


Figure 4: Fusion at the feature level

4.2 Multi-snake

For this approach, the energy function includes a new term called E_{temp} which is a temporal term defined under the hypothesis of monotony of the evolution: the object always moves in the same direction. This internal multi-temporal energy is computed with the following steps:

- Searching of the normal $\mathcal{N}$ to the segment defined by the preceding and following points of the current image $[P_k^{n-1}; P_k^{n+1}]$.
- Projection on $\mathcal{N}$ of the positions of the points n in the preceding and following images (P_{k-1}^n, P_{k+1}^n), and the point whose position is evaluated (P_k^n). Those projections are called Q_{k-1}^n, Q_k^n, and Q_{k+1}^n.
- Computation of the temporal energy of the multi-snake: If Q_k^n belongs to the segment $[Q_{k-1}^n\,; Q_{k+1}^n]$ the point is considered as normally placed, its temporal energy is null. On the other hand, if Q_k^n isn't in the segement $[Q_{k-1}^n\,; Q_{k+1}^n]$, its positionning is considered wrong and the temporal energy will be the distance between the point and the segment.

	initialization	propagation	multi-snake
image 1	1.89	2.35	2.16
image 2	2.03	2.54	2.01
image 3	2.87	2.42	2.28
image 4	4.73	3.03	2.51
image 5	4.86	5.95	1.83
image 6	8.74	9.28	2.53
image 7	9.91	11.19	5.35
image 8	16.15	15.33	6.76

Table 5: Distances between the manually drawn references and the initialization, proapgation results obtained by the causal approach and results obtained by the multi-snake

For this approach, the geophysicist gives a rough initialization of the object on the image of the data-set which has the best contrast surrounding the sought after area. All the contours are calculated at the same time with both spatial and temporal energy terms.

The results obtained with the multi-snakes are very good when the displacement is not too important compared to the searching window. In that case for the last two images, the distance between the result increases because of a large displacement. Results can be improved by increasing the search window (e.g. 7x7 window) or using multi-resolution techniques.

5 Conclusion

In this paper, we presented different fusion techniques using multi-temporal active contours to find the location of various objects in two SAR images data-sets. A quantitative assessment showed that: the fusion at the data level gives better results than the fusion at the feature level for stable objects, and multi-snakes give better results than propagation by initialization for moving objects.

References

[1] M. Kass, A. Witkin, and D. Terzopoulos. Snakes: active contour model. *International Journal of Computer Vision*, 1:321–332, January 1988.

[2] R. Touzi, A. Lopès, and P. Bousquet. A statistical and geometrical edge detector for SAR images. *IEEE Trans. Geosci. and Remote Sensing*, 15(3):764–773, 1988.

[3] G. Borgefors. Distance transformation in digital images. *CVGIP*, 34:344–371, 1986.

[4] E. Trouvé, Y. Chambenoit, N. Classeau, and Ph. Bolon. Statistical and operational performance assessment of multitemporal SAR image filtering. *IEEE Trans. Geosci. and Remote Sensing*, to appear, Nov. 2003.