Contour tracking on sequences of ventriculographic images: a comparison between gradient of Gaussian and first order absolute moment.

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Abstract. In this paper the properties of both the GoG and FOAM operators, as well as the results obtained with their respective localization procedures, are compared. FOAM (first order absolute moment) and GoG (gradient of Gaussian) filters are used to enhance the discontinuities between the gray levels of the different structures of the images. The contour we are tracking is then localized through the filtered images by starting from an approximate contour. Results of the two automatic contour tracking procedures are presented on sequences of ventriculographic and synthetic images.

Keywords: edge detection, contour tracking, ventriculography.

1 Introduction

Adequate procedures to detect contours automatically are particularly needed when processing sequences of cardiovascular images. In this field the number of images to be processed is, in general, so large that a manual tracing phase proves unacceptable. A contour detection algorithm usually requires two steps; first the discontinuities between the gray levels of the different structures of the images are enhanced by means of a filtering process, and second the points of the contour we are looking for are localized through the filtered images. First and second order derivatives are widely used to enhance the gray level discontinuities while a low pass prefilter is introduced to cope with noise. The gradient of Gaussian (GoG) is the first order derivative operator most frequently used in literature to enhance the luminance variations with a ridge. However, a similar ridge map can be provided by a filter which is obtained from the generalization of the first order absolute moment (FOAM). Unlike the GoG filter, the FOAM filter provides ridges at both edges and lines and gives rise to local maxima of the ridges at line endings, corners and junctions [1]. In this work the properties of the two GoG and FOAM operators, as well as the results obtained with their respective localization procedures, are compared.

2 The Contour Tracking Approach

When an approximate contour C_a is traced manually by an operator on the first frame of the sequence, the "true" contours C_i can be estimated from C_a as follows:

I. The images are processed by means of a two-dimensional operator giving a null result on homogeneous regions and a ridge at the gray level discontinuities. In the representations so obtained (edge maps) the contours C_i are the top lines of the ridges.
II. Every point of C_a is brought to the top of the respective ridge along a computed direction.
III. Let the sample rate of the temporal sequence be high enough to allow the true contour C_i to lie within the $(i+1)^{th}$ ridge. Thus, when the C_1 contour is determined it can be used as the starting contour to determine contour C_2 on the next frame and so on.

3 The filtering process

Let *f(x,y)* be the gray level map of an image and let Θ be a circular domain, the generalized first order absolute moment is computed as follows:

$$e(x,y) = \iint_{\Theta} \left| f_1(x,y) - f_2(x-\tau_x, y-\tau_y) \right| g_3(\tau_x,\tau_y)\, d\tau_x d\tau_y$$
$$f_1(x,y) = f(x,y) * g_1(x,y) \qquad f_2(x,y) = f(x,y) * g_2(x,y) \tag{1}$$

where three Gaussians with unitary integral are adopted for the functions $g_1(x,y)$, $g_2(x,y)$ and $g_3(x,y)$.
Let us associate every point of the domain Θ to a mass $m(\tau_x,\tau_y)$ so that:

$$m(\tau_x,\tau_y) = \left| f_1(x,y) - f_2(x-\tau_x, y-\tau_y) \right| g_3(\tau_x,\tau_y) \tag{2}$$

We will call the mass center of the function $m(\tau_x,\tau_y)$ "center of mass of the first order absolute moment". The center of mass of the first order absolute moment is obtained by computing the vector **b**(x,y):

$$\mathbf{b}(x,y) = \frac{1}{e(x,y)} \iint_{\Theta} \boldsymbol{\tau} \left| f_1(x,y) - f_2(x-\tau_x, y-\tau_y) \right| g_3(\tau_x,\tau_y)\, d\tau_x d\tau_y \tag{3}$$

where $\boldsymbol{\tau}$ is the vector with τ_x,τ_y components. While function *e*(x,y) provides the ridge map of the image, vector **b** provides the direction of the path which joins every point of the starting contour to the nearest point of the ridge top [2].
The amplitude of the gradient of Gaussian is computed as follows:

$$h(x,y) = \left[\frac{\partial}{\partial x} \left[f(x,y) * g_3(x,y) \right] \right]^2 + \left[\frac{\partial}{\partial y} \left[f(x,y) * g_3(x,y) \right] \right]^2 \tag{4}$$

While function h(x,y) provides the ridge map, the gradient **v** of the ridge map provides the direction of the path which joins every point of the starting contour to the nearest point of the ridge top [3].

4 Comparison between GoG and FOAM

The localization procedures take every single point of an approximate contour to the top of the ridges provided by the GoG and FOAM filters. The final contour is obtained by computing the values of the ridge maps along the path given by vector **v** and **b** respectively, until a local maximum is reached. The path length is bounded to the radius r of the circular domain Θ. In order to evaluate only the properties and drawbacks of using the two ridge maps, no additional regularization criteria were used, except for the low pass filters of the GoG and FOAM operators.

	GoG			FOAM $\sigma1=2$ $\sigma2=0.67$			FOAM $\sigma1=2.67$ $\sigma2=1.33$		
Δ	PRM1	PRM2	PRM3	PRM1	PRM2	PRM3	PRM1	PRM2	PRM3
0	100	100	77	100	100	91	100	100	93
1	100	100	92	100	100	99	100	100	98
2	100	100	93	100	100	99	100	100	98
3	100	100	95	100	100	100	100	100	99
4	100	100	95	100	100	100	100	100	100
5	100	100	75	100	100	82	100	100	86
6	100	100	45	100	100	61	100	100	69
7	100	96	28	100	100	55	100	100	64
8	95	78	13	98	98	48	100	100	56
9	82	40	6	91	91	36	98	98	46
10	57	18	2	76	74	23	90	90	29
11	38	8	2	53	47	14	70	69	18

Table 1. The percentage of points of the starting contour which reach the discontinuity versus the distance of the starting contour from the discontinuity. The size of both operators is σ_3=3 pixel.

Let Δ be the distance between the starting contour and a straight step discontinuity; in Table 1 three parameters relating to the robustness of the automatic contour tracking procedures are reported:

I. PRM1: Percentage of points of the starting contour which reach the discontinuity; the path direction is chosen perpendicularly to the discontinuity.
II. PRM2: Percentage of points of the starting contour which reach the discontinuity; the path direction is computed.
III. PRM3: Percentage of points of the starting contour which reach the nearest point of the discontinuity; the path direction is computed.

PRM1 reveals only those errors due to the presence of spurious local maxima of the ridge profile. If Δ is small with respect to the size of the operator, then no errors arise in the localization process: gaussian filters regularize both operators well enough and there are no spurious local maxima close to the discontinuity. As Δ increases, PRM1 decreases due to the presence of spurious local maxima which are far from the

discontinuity. Table 1 shows that when the path direction is given, both GoG and FOAM operators behave in the same way.
PRM2 highlights both spurius local maxima and wrong path direction. While PRM2 is lower than PRM1 if a GoG operator is used, no significant differences between the two parameters are present if FOAM is adopted. Therefore, the computation of the center of mass of the FOAM is more robust to noise than the computation of the gradient of the GoG map. In figure 1 the results of the procedure applied on a synthetic image are presented: localization is better if FOAM operator is used.

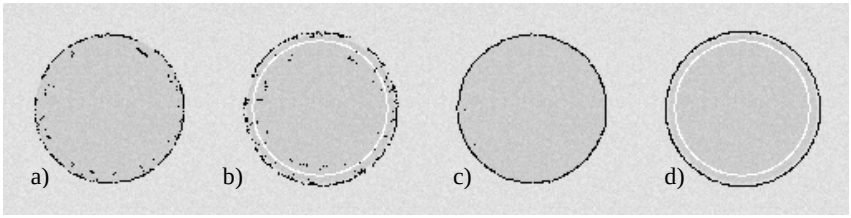

Figure 1. The test image is a step discontinuity of 20 affected by additive Gaussian noise with σ=10. The starting contour is the white inner circular contour (Δ=8 pixels). In a),b) the GoG filter is used; in c),d) the FOAM filter is used. In a),c) the final contour is shown; in b),d) the ending points of the paths $r \cdot \mathbf{v}/|\mathbf{v}|$ and $r \cdot \mathbf{b}/|\mathbf{b}|$, respectively, are shown.

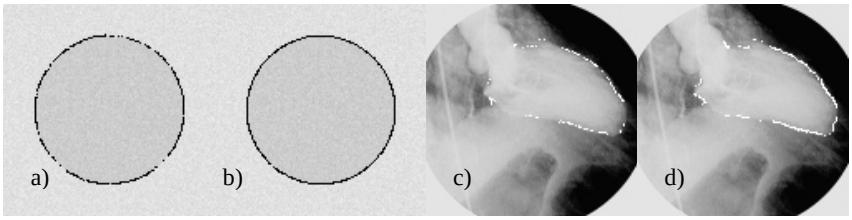

Figure 2. The final contours on sequences of synthetic and ventriculigraphics images using GoG a),c) and FOAM b),d).

PRM3 highlights mainly localization errors which arise when the approximate contour is close to the discontinuity. The amplitude of vector **v** is small on the top of the ridge (very close to the discontinuity). Therefore, errors arise in computation of the direction because of the presence of noise. The amplitude of vector **b** is also small when points near the discontinuity are considered. However, as regards FOAM, a simple rule can be applied to the localization procedure i.e. “if the distance from the starting point to the center of mass is less then 1 pixel than the final point is the same as the starting point”. If this rule is applied than PRM3 is approximately equal to 100% when Δ=0. The same rule cannot be applied when using GoG because the amplitude of vector **v** is small both at the top of the ridge and on the two tails of the ridge. In sequences where discontinuities move very slowly this error gives rise to a movement of the points along the contour itself. In figure 2-a),b) the effect of this error in a synthetic sequence is presented; the contour we are searching for does not move and the images of the sequence differ only according to the noise added. Let the approximate starting contour be the true contour itself, it can be observed that some of

the points move leaving gaps in the final contour. In figure 2-c),d) automatic contour tracking on 10 frames of a ventriculographic sequence where motion is slow is presented.

5 Conclusion and results

Sequences of images of left ventricles, recorded in low dose digital angiography, were used to test the localization procedures. Figure 3 shows the results provided by the automatic contour tracking procedure over a 28 frame sequence when the FOAM filter is used. The approximate starting contour is a polygonal line and it is traced manually on the first frame of the sequence. When FOAM was used, localization performances increased and only a few points shifted along the contour. The better performance of the localization procedure was mainly due to the better results obtained in the computation of the path direction. When contrast material decreases, failure to localize some points of the contour occurs. In order to deal with this kind of error additional constraints must be added to regularize the localization procedure [4].

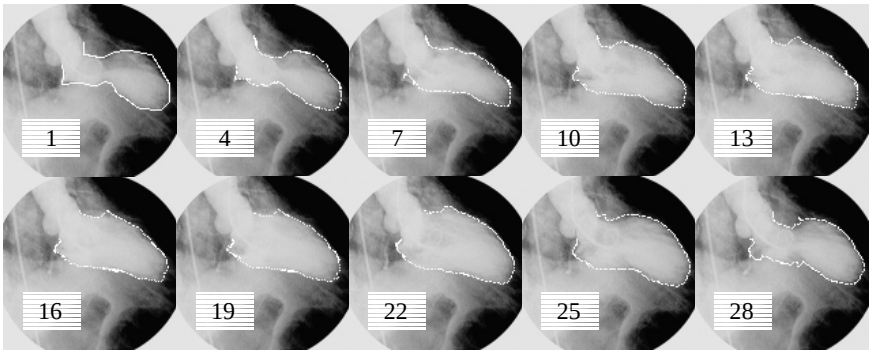

Figure 3. Results of the automatic contour tracking procedure over a sequence of 28 ventriculographics images.

References

1. M. Demi, M. Paterni, The first order absolute moment in low-level image processing, *DSP97,* 1997, pp. 511-514.
2. M.Paterni, M.Demi, C.Morizzo, M.Kozakova, C.Palombo, The First Order Absolute Moment in Contour Tracking, *Proc. Computers in Cardiology*, 1997, pp. 545-548
3. D.Marr, Vision, *Freeman*, New York 1982.
4. M.Bertero, T.A.Poggio, Ill-Posed Problems in Early Vision, *Proceeding of the IEEE*, vol. 76, n. 8, August 1988.