Segmentation of complex shapes by adaptive energy forces

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ABSTRACT

The classical gradient vector flow technique, to some extent has the ability to catch up dynamic topological changes, and therefore to extract complex shapes. Due to the reliance on the detected edges and the corresponding strength, the snake may be obstructed to rest on the ideal contours. To remedy these two deficiencies, a new deformable model is proposed in this paper. The idea is to improve the energy function by consistently reducing the Euclidean distance between the initial centroid and the estimated one of the snake. This is achieved by applying the mean shift for estimating the varied centroid of the snake during the iteration, which indicates the balance point of the overall forces. Experimental results show favorable performance of the proposed approach.

Keywords

Deformable model, gradient vector flow, topology, energy force, mean shift

1 INTRODUCTION

In this paper, we propose an improved gradient vector flow for segmenting concave regions. It has been observed that the classical snakes as well as the GVF cannot move towards the true concave boundaries *if the net effect of the internal and external (and damping) forces has reached zero during iteration*. An intuitive idea is to intelligently break this "false balance", and then encourage the snake to march until it is located at the real boundaries. Therefore, the segmentation problem anticipates an in-depth study on the energy dynamics, based on the deformable model as follows: $E_t = \int_\Omega (\alpha \parallel C(s)' \parallel^2 + \beta \parallel C(s)'' \parallel^2 + P(C(s)))ds$, where the former two terms represent the internal energy, and the later one is the external energy. Additionally, α and β are the tension and rigidity terms respectively. $C(s)$ is the contour that delineates the desired boundaries, and $s \in$[0,1]. P is defined as $P = - \parallel \bigtriangledown I \parallel$, where I is the image intensity.

Our research is motivated by seeking a new dynamic energy fomulation, which may be used to adapt the internal and external forces in case a false energy balance happens near to the real boundaries. To achieve this, a mixed model of the GVF scheme and the mean shift technique is hence proposed. This model is based on the fact that the centre of the weight of the snake normally is away from that of the ideal boundary when the former fails to settle on the latter. One example is illustrated in Fig. 2.

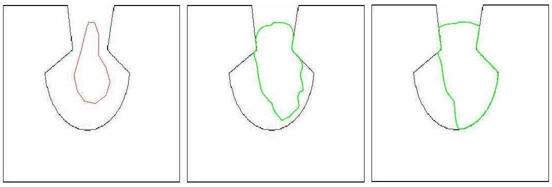
(a) (b) (c)

Figure 1: An example that shows the performence of the GVF on a synthetic concave shape.

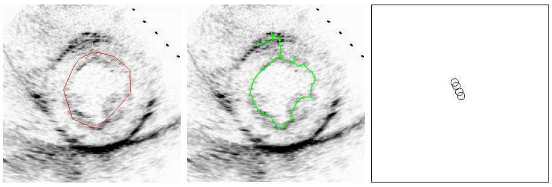
(a) Start (b) End (c) Centroid

Figure 2: Movement of the centroid of the snake during the iteration.

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2 GVF snake

The GVF snake yields an external force field called *GVF field* in the continuous gradient domain [XP97]. Technically, a binary edge map is demanding, which forces the snake to effectively approach the edge-like areas. When the GVF snake is finally settled, where the internal and external forces are balanced, we shall have the relationship as

$$\alpha C''(s) - \beta C''''(s) + \gamma V = 0, \qquad (1)$$

where γ is a proportional coefficient. Alternatively, one can modify Eq. 1 to be

$$\lambda_\alpha C''(s) - \lambda_\beta C''''(s) + \gamma V = 0, \qquad (2)$$

where λ_α and λ_β stand for the contributions of the elasticity and rigidity in the internal energy term. To generate the representation for λ_α and λ_β, we introduce a mean shift based framework.

3 Mean shift

Mean shift is employed to search for a contour candidate that has the most similar characteristics to that of the target contour. To efficiently constrain the contour propogation, the CAMSHIFT algorithm by [Bra98] is used due to its preference of accounting for dynamically changing distributions during the evolution.

To exploit the CAMSHIFT algorithm, we first calculate the zeroth moment M_{00}, moment M_{10} for x-coordinates, and moment M_{01} for y-coordinates of image points on the contour candidate. This requires an estimate of the Euclidean distance between the origin (0,0) and individual points before the moment calculation is conducted. The centroid (x_c, y_c) of the contour is then calculated by $x_c = M_{10}/M_{00}$ and $y_c = M_{01}/M_{00}$. The Euclidean distance d_e between the initial centroid and the estimated one is consistently calculated so that λ_α and λ_β can be estimated by $\lambda_\alpha = \alpha d_e$, and $\lambda_\beta = \frac{\beta}{d_e}$. If $d_e \leq 1$ and Eq. 2 holds, then the evolution will stop as the convergence to the target contour has been reached; otherwise, the search has to continue.

4 EXPERIMENTAL RESULTS

A couple of synthetic and real images have been tested using the proposed mean shift based algorithm. The first one is the synthetic image demonstrated in Fig. 1, where the GVF snake is leaking. Before the segmentation is conducted, the snake and its centroid need to be initiated, both of which have been illustrated in Fig. 3 (a). Fig. 3 shows that the proposed snake model properly outlines the concave shape.

The second one is a short-axis cardiac ultrasonic image. This human heart image consists of a number of structures besides the endocardial border shown in Fig. 4. According to Fig. 2 and 4, our approach has better performance on the border segmentation than the classical GVF algorithm.

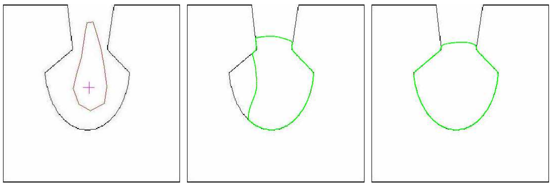
(a) (b) (c)

Figure 3: Segmentation of the synthetic image shown in Fig. 1, where '+' shows the position of the initial centroid ($\alpha = 0.05; \beta = 0; \gamma = 1; \mu = 0.1$).

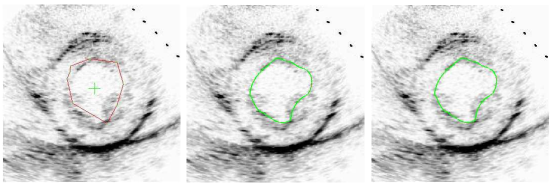
(a) (b) (c)

Figure 4: Segmentation of the cardiac image shown in Fig. 2 ($\alpha = 0.05; \beta = 0; \gamma = 1; \mu = 0.1$).

5 CONCLUSION

This paper has presented a novel algorithm for image segmentation, integrating the classical GVF algorithm and the mean shift technique. The experimental results demonstrate that the new approach has favourable performance in segmenting concave boundaries as well as in different scenes.

6 Acknowledgements

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References

[Bra98] Gary R. Bradski. Real time face and object tracking as a component of a perceptual user interface. In *Proceedings of the 4th IEEE Workshop on Applications of Computer Vision (WACV'98)*, page 214. IEEE Computer Society, 1998.

[XP97] Chenyang Xu and Jerry L. Prince. Gradient vector flow: A new external force for snakes. In *Proceedings of the 1997 Conference on Computer Vision and Pattern Recognition (CVPR '97)*, pages 66–72. IEEE Computer Society, 1997.