Estimation of multiple objects at unknown locations with active contours

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Abstract

This paper presents an algorithm for the estimation of multiple regions with unknown shapes and positions using multiple active contour models (ACM's). The algorithm organizes edge points into strokes and computes the association between those strokes and the ACM's using the component wise EM algorithm (CEM) for MAP estimation. The algorithm is randomly initialized with a high number of ACM's and performs online model selection using importance sampling. This algorithm was recently presented in more detail in IbPRIA 2007 [1].

1. Introduction

Active contour models (ACM's) or snakes have been extensively used to estimate object boundaries in images. However, their difficulties with initialization and outlier rejection are still unsolved problems. In addition, most of the research done on ACM's tries to estimate a single region using one elastic model and little research has addressed estimation of multiple elastic models. In this paper we present a method for the automatic segmentation of multiple regions which, in simultaneous with shape estimation, deals with the problem of sensitivity to the initialization and robustness to outliers. The initialization of the ACM's is random and the algorithm selects the number of ACM's automatically.

2 Problem formulation

Given an image with an unknown number of objects and assuming that is is possible to detect connected sets of edge points belonging to the objects boundaries, our aim is to connect segments belonging to individual object and to discard outlier segments associated with spurious edges. Let y be the set of all edge points detected in an image and let us assume that y is organized in connected components, called strokes, $y^j, j = 1, ..., N$. We will assume for now that the number of ACM's, L is known and we add an extra model to account for outliers. We denote it the outlier model, $x^{outlier}$. Let x^k be the the k-th active contour model, $k = 1, ..., L$. We will assume that the strokes detected in the image are independent:

$$p(y|x) = \prod_j p(y^j|x) \quad (1)$$

and that the distribution of each stroke is a mixture of L+1 densities:

$$p(y^j|x) = \sum_k \alpha_k p(y^j|x^k) + \alpha_{outlier} p(y^j|x^{outlier}) \quad (2)$$

where the α_k's are the mixing proportions verifying $\alpha_k \geq 0$, $\alpha_{outlier} \geq 0$ and $\sum_k \alpha_k + \alpha_{outlier} = 1$.

Our aim is to estimate the ACM's and also their number L. We will iteratively estimate the ACM's using the MAP criterion and assuming L is fixed:

$$x^* = \arg\max_x p(x|y) = \arg\max_x [\log p(y|x) + \log p(x)] \quad (3)$$

The distributions involved in this problem are detailed in [1].

3 Unsupervised multiple active contours estimation

The algorithm proposed in [2] described the estimation of multiple models in which multiple ACM's compete for the boundaries of the multiple regions. The algorithm solves the association between strokes and multiple models problem and also the outlier rejection using the Component Wise EM algorithm. However it does not solve the initialization problem and the estimation of the number of models. To deal with these difficulties we initiate the algorithm with an arbitrary large number of snakes, L. The initialization of these L ACM's is fully automatic; circular ACM's are randomly distributed throughout the image, inside the strokes bounding boxes. The size of the circles is defined by the average size of the bounding boxes or may be user defined. Then the algorithm iteratively performs the following two steps.

1. Update

   The ACM's are sequentially updated with the Component wise EM algorithm. More details can be found in [2]. Convergence is achieved when all the points move less than a threshold.

2. Sampling

   The algorithm relocates the ACM's by performing Importance Sampling using the mixing proportions α_k as the importance function. The set of ACM's $x^k, k = 1, ...L$ is sampled in order to obtain a new set of L ACM's with the highest values of α_k. Obviously some ACM's will be sampled several times and other will not be sampled at all. The ACM's that are not sampled are eliminated and the ones that were sampled several times will give rise to new ACM's that are equal. However the CEM algorithm will insure they will converge to different locations since they are updated one at a time.

The sampling step does not change the number of ACM's. Therefore, in order to reduce the number of ACM's, we add a model elimination step every P iterations. In this step we eliminate multiple copies of the models which were sampled several times and keep only one realization of such ACM. The number of different ACM's is the estimated number of models.

4 Experimental Results

This section presents an example to illustrate the performance of the proposed method. This example illustrates the application of the algorithm to a blood cell image using the outlier model to discard the smaller objects. The algorithm was initialized with 120 ACM's and in the final segmentation 27 contours remain. Fig. 1 shows the initial contours on the left, the final contours in the middle and the strokes classified as outliers on the right. The outliers that were detected correspond to the smaller strokes present in the image.

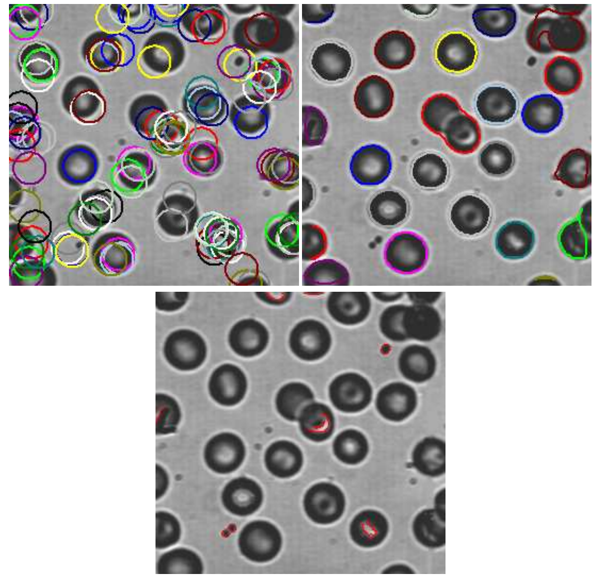

Figure 1. Cell example; 120 initial contours (left), 27 contour estimates (right) and outlier strokes (bottom).

5 Conclusions

This paper presents an algorithm for the extraction of multiple regions using multiple active contour models (ACM's). Initialization is automatic, the algorithm estimates the number of models and also accounts for outlier features detected in the image. It is shown that the proposed algorithm is able to robustly estimate all the deformable contours and to compute the association probability between strokes and multiple models.

6 Acknowledgments

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References

[1] Margarida Silveira, Jorge S. Marques, "Estimation of multiple objects at unknown locations with active contours", Lecture Notes in Computer Science - Pattern Recognition and Image Analysis , IbPRIA 2007, Vol. 4478, pp. 372-379, Girona, Spain, June 2007.

[2] Silveira, M. and Marques, J., Multiple Active Contour Models based on the EM algorithm, IEEE International Conference on Image Processing, ICIP 2005, Genova, Italy, September 2005.