

## A MULTI-RESOLUTION STOCHASTIC LEVEL SET METHOD FOR THE MUMFORD-SHAH SEGMENTATION OF BIOIMAGES

Yan Nei Law<sup>1</sup>, Hwee Kuan Lee<sup>1</sup>, \*Andy M. Yip<sup>2</sup>

<sup>1</sup> Imaging Informatics Group  
Bioinformatics Institute, A\*STAR  
30 Biopolis Street, #07-01 Matrix  
Singapore 138671  
{lawyn, leehk}@bii.a-star.edu.sg  
www.bii.a-star.edu.sg

<sup>2</sup> Department of Mathematics  
National University of Singapore  
2, Science Drive 2  
Singapore 117543  
andyyip@nus.edu.sg  
www.math.nus.edu.sg

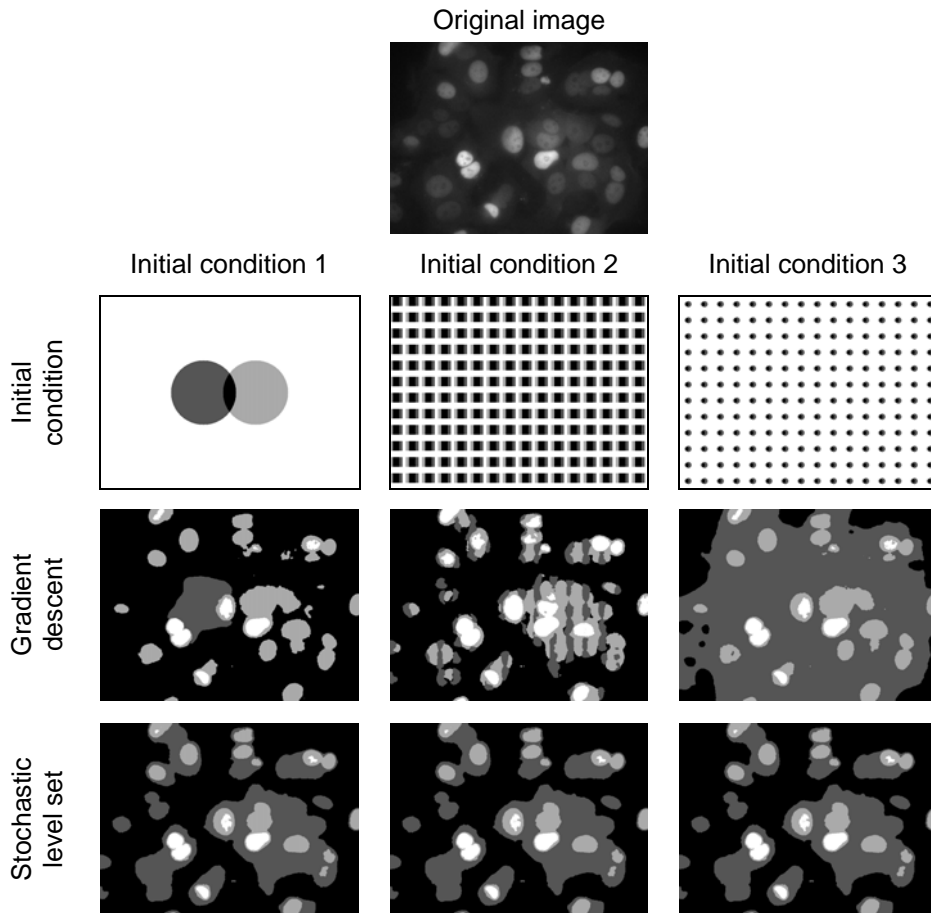
**Key Words:** *Image segmentation, multi-resolution, level set method, Mumford-Shah model, basin hopping, stochastic level set*

### ABSTRACT

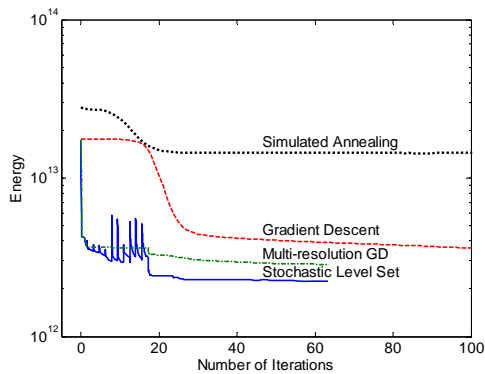
**Motivation:** Image segmentation is indispensable in bioimaging applications. Due to the complex nature of bioimages, optimization model based methods often give the best segmentation results, provided that the underlying optimization problem is solved accurately. The Mumford-Shah model [1] is one of the most successful image segmentation models. But existing algorithms for the model require a good initial guess to obtain good results and are therefore impractical. To make the model practical, it is essential to develop an algorithm which can compute the global or near global optimal solution efficiently. While gradient descent based methods are well-known to find a local minimum only, even many stochastic methods do not provide a practical solution to this problem either.

**Result:** We propose a hybrid approach which combines gradient based and stochastic optimization methods to resolve the problem of sensitivity to the initial guess (see Fig. 1). At the heart of our algorithm is a well-designed basin hopping scheme [2] which uses global updates to escape from local traps in a way that is much more effective than standard stochastic methods. In our experiments, a very high quality solution is obtained within a few stochastic hops whereas the solutions obtained with other standard stochastic methods are incomparable even after thousands of steps. We also propose a multi-resolution approach to reduce the computational cost and enhance the search for the global minimum (see Fig. 2). Furthermore, we derived a simple but useful theoretical result relating solutions at different resolutions.

The proposed method works very well even for images with a high level of noise and wide spread intensity levels such as those from live cell microscopy. Moreover, it can detect objects without sharp boundary, objects with complex shape and clusters of small objects. We validated the method using images obtained from microscopy and MRI. The results show that the algorithm can accurately extract useful structures such as nuclei, brain tumors and proliferation marker PCNA in the images.



**Figure 1.** Robustness to the initial segmentation. The standard gradient flow using level set method is very sensitive to the initial segmentation. The proposed stochastic level set method can resolve the problem effectively by combining stochastic and deterministic optimization techniques.



**Figure 2.** Convergence rate. The proposed stochastic level set method uses a hybrid method (stochastic + deterministic) to search for a global minimum and uses a multi-resolution approach to speed up the computation. It reaches a much lower energy in a smaller number of steps than other competitive methods.

## REFERENCES

- [1] D. Mumford and J. Shah, "Optimal approximation by piecewise smooth functions and associated variational problems", *Comm. Pure Appl. Math.*, Vol 42, pp. 557-685, (1989).
- [2] D.J. Wales and J.P.K. Doye, "Global optimization by basin-hopping and the lowest energy structure of Lennard-Jones clusters containing up to 110 atoms", *Journal of Physical Chemistry A*, Vol. 101, pp. 5111-5116, (1997).