Dark Spots Extraction from Oil Spill SAR Image Using a Irregular Marked Point Process

Jie Li, Qianguo Xing

Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Shandong Yantai, China
University of Chinese Academy of Sciences, Beijing, China
E-mail: 357221180@qq.com, xingqg@163.com

ABSTRACT

• Aiming at the difficulty to determine the geometric shapes of the dark spots in oil spill SAR image, a dark spots extraction method based on irregular marked point process is proposed. The proposed method combines the irregular marked point process, Bayesian inference and Reversible Jump Markov Chain Monte Carlo algorithm (RJMCMC).

INTRODUCTION

• Oil pollution belongs to the most widespread man-caused emergency situations considerably harming ocean ecosystems and different types of economic activities. Earth observation satellite sensors have proved to be a cost-effective, all-weather and all-day early warning way to help identify and monitor oil-spills before they cause widespread damage. Synthetic Aperture Radar (SAR) sensors with all weather, day and night, large area observation capabilities are a convenient and effective tool for oil spill monitoring. The detectability of oil spill by SAR sensors is based on the fact that oil slicks dampen the Bragg waves on the ocean surface and reduce the radar backscatter coefficient. This results in dark regions or spots in SAR images.

• Dark spots extraction is an important task of oil spill detection. However, due to the characteristics of continual drift and diffusion over time, it is difficult to determine the geometric shapes of dark spots. This research proposes an extraction method which could determine the dark spots shapes effectively.

OBJECTIVE

• Simulated SAR image and Radarsat-1/2 SAR images are used in this research.

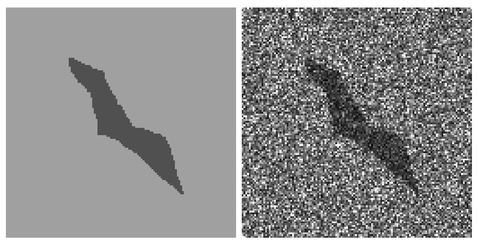


Fig.1 Geometric template and simulated SAR image

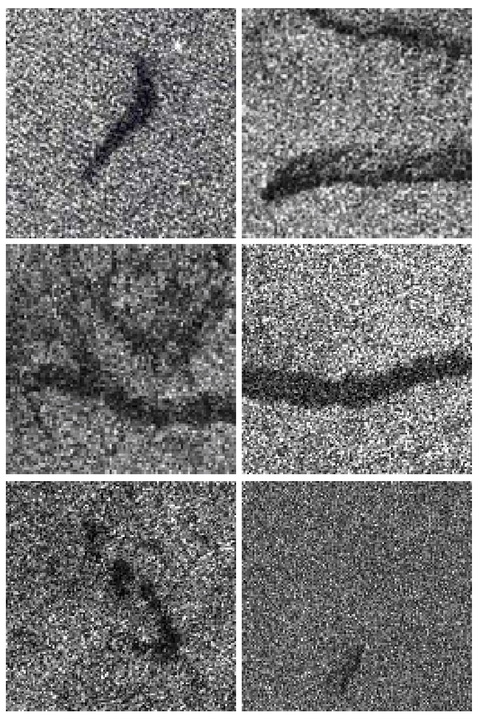


Fig.2 Real SAR images

METHOD

• **Intensity models of SAR images**

$$p(\boldsymbol{Z}\mid\boldsymbol{\beta},\boldsymbol{G},m,\boldsymbol{P},\boldsymbol{k})=\prod_{j=1}^{m}\prod_{Z_i\in Q_j}\frac{Z_i^{\alpha_o-1}}{\Gamma(\alpha_o)\beta_o^{\alpha_o}}\exp\left(-\frac{Z_i}{\beta_o}\right)\times\prod_{Z_i\in \boldsymbol{Z}_b}\frac{Z_i^{\alpha_b-1}}{\Gamma(\alpha_b)\beta_b^{\alpha_b}}\exp\left(-\frac{Z_i}{\beta_b}\right)$$

• **Dark spots extraction models**

$$p(\boldsymbol{\beta},\boldsymbol{G},m,\boldsymbol{P},\boldsymbol{k}\mid\boldsymbol{Z})\propto p(\boldsymbol{Z}\mid\boldsymbol{\beta},\boldsymbol{G},m,\boldsymbol{P},\boldsymbol{k})\,p(\boldsymbol{\beta})\,p(m)\,p(\boldsymbol{G}\mid m)\,p(\boldsymbol{P}\mid m,\boldsymbol{G})\,p(\boldsymbol{k}\mid m,\boldsymbol{G})$$

$$=\prod_{j=1}^{m}\prod_{Z_i\in Q_j}\frac{Z_i^{\alpha_o-1}}{\Gamma(\alpha_o)\beta_o^{\alpha_o}}\exp\left(-\frac{Z_i}{\beta_o}\right)\times\prod_{Z_i\in \boldsymbol{Z}_b}\frac{Z_i^{\alpha_b-1}}{\Gamma(\alpha_b)\beta_b^{\alpha_b}}\exp\left(-\frac{Z_i}{\beta_b}\right)\times\frac{1}{\sqrt{2\pi}\sigma_o}\exp\left(-\frac{(\beta_o-\mu_o)^2}{2\sigma_o{}^2}\right)\times$$

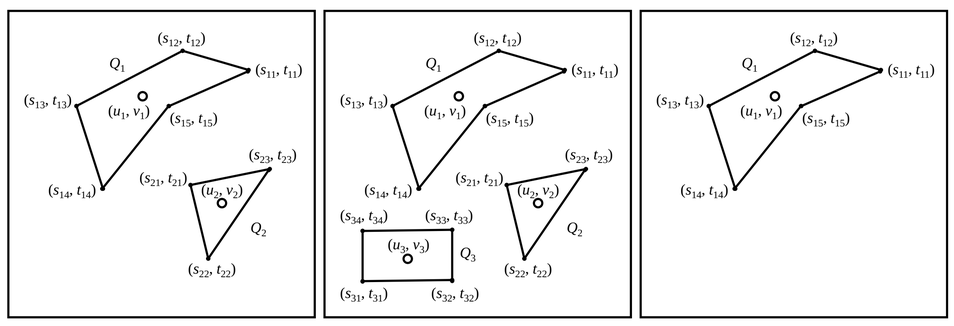
$$\frac{1}{\sqrt{2\pi}\sigma_b}\exp\left(-\frac{(\beta_b-\mu_b)^2}{2\sigma_b{}^2}\right)\times\frac{\lambda^m}{m!}\exp(-\lambda)\times|\boldsymbol{D}|^{-m}|\boldsymbol{D}|^{-\sum_{j=1}^{m}k_j}\times\prod_{j=1}^{m}\frac{\tau^{k_j}}{k_j!}\exp(-\tau)$$

• **Simulation**

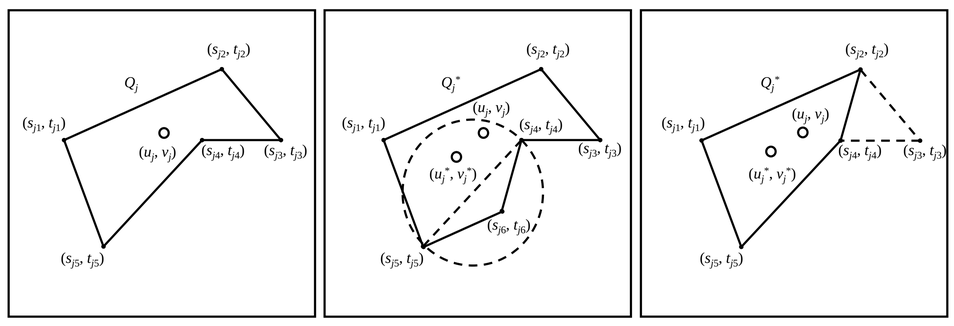
The Metropolis-Hastings and RJMCMC algorithms are used to simulate dependent samples from the posterior distribution of $\boldsymbol{\Theta}=(\boldsymbol{\beta},\boldsymbol{G},m,\boldsymbol{P},\boldsymbol{k})$ while the parameter space is variable during sampling. The move types designed in this research include:

(1) Move 1: updating scale parameters $\boldsymbol{\beta}$

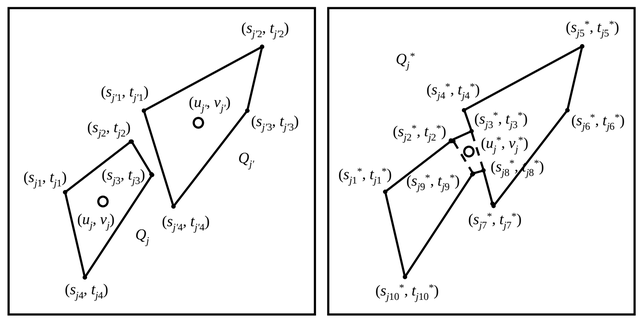
(2) Move 2: add or remove polygons



(3) Move 3: add or remove polygons nodes



(4) Move 4: polygons merged



• **Optimization**

The MAP estimation is used to obtain optimal parameters $\boldsymbol{\Theta}_{\mathrm{MAP}}$.

$$\boldsymbol{\Theta}_{\mathrm{MAP}}=\arg\{\max p(\boldsymbol{\beta},\boldsymbol{G},m,\boldsymbol{P},\boldsymbol{k}\mid\boldsymbol{Z})\}$$

RESULTS

• **Extraction process of simulated SAR image**

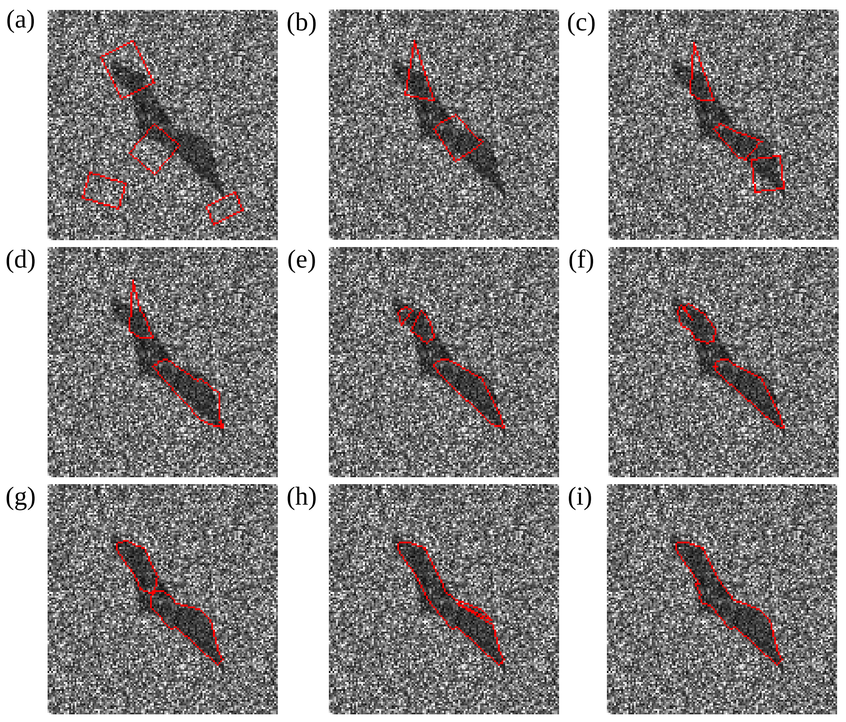


Fig.3 (a) shows the initial positions of the dark spot, (b)-(i) show the positions and geometric shapes of the dark spot after 40, 100, 130, 180, 260, 1590, 1850 and 2000 iterations, respectively.

RESULTS

• **Experiment results of real SAR images**

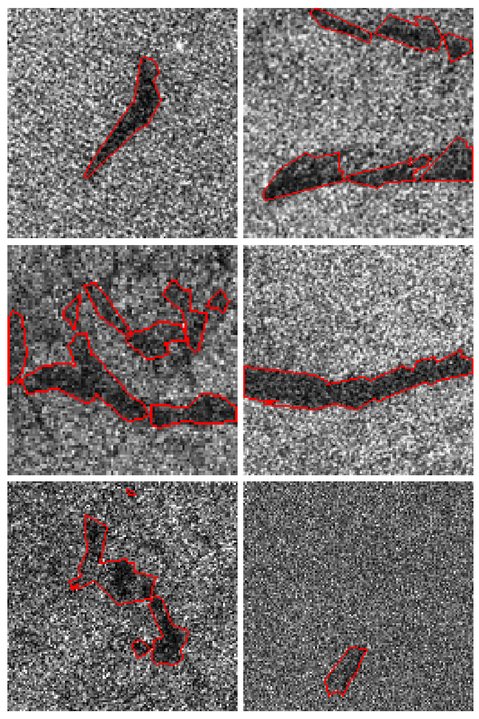
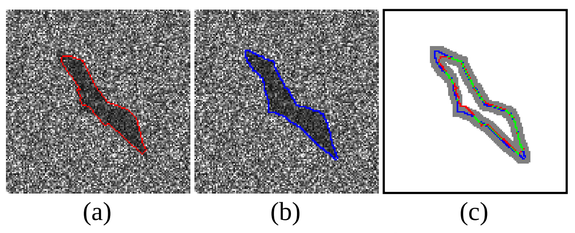


Fig.4 Extraction results of Radarsat-1/2 SAR images

DISCUSSION

• **Visual assessment**



(a) (b) (c)

Fig.4 (a) shows the dark spot outline of proposed method, (b) shows the real outline, (c) shows the overlay result of two outlines

• **Confusion matrix and statistical measurements**

	Dark spots	Back ground	Total	Producer's accuracy
Dark spots	1052	30	1082	97.23
Back ground	156	15146	15302	98.98
Total	1208	15176	16384	
User's accuracy	87.09	99.80		
Overall accuracy	98.86		Kappa coefficient	0.9127

CONCLUSION

• This research proposes an oil spill extraction method which could determine the dark spots shapes effectively. The proposed method combines the irregular marked point process, Bayesian inference and Reversible Jump Markov Chain Monte Carlo algorithm (RJMCMC). The extraction results demonstrate that the proposed method could locate and extract dark spots effectively.

MAJOR REFERENCES

• Li Y, Li J. Oil spill detection from SAR intensity imagery using a marked point process [J]. Remote Sensing of Environment.
• Gilks W R, Richardson S, Spiegelhalter D J. Markov Chain Monte Carlo in Practice [M].
• Green P J. Reversible jump Markov chain Monte Carlo computation and Bayesian model determination [J]. Biometrika.

中国科学院烟台海岸带研究所 Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences
中国科学院大学 University of Chinese Academy of Sciences

Acknowledgements: This work is supported by Chinese Academy of Sciences key instrument project (No. YJKYYQ20170048), the National Natural Science Foundation of China (No.41676171), and the Qingdao National Laboratory for Marine Science and Technology of China (No.2016ASKJ02). Thanks to Canadian Space Agency for providing space science and application data products of Radarsat-1/2.