Algorithms for automatic detection of oil spills in SAR images (ADOS)

Final report

Anne S. Solberg, Department of Informatics, University of Oslo

This report describes the work done in the ADOS project. The project's main purpose was to fund a Ph.D study for Camilla Brekke. The project started in 2003 and Camilla Brekke submitted her Ph.D. thesis in August 2007. The thesis is currently under evalution.

The focus of this project is on detecting marine oil spills using spaceborne synthetic aperture radar images. Oil spills on the sea surface are seen often, and they correlate well with major shipping routes and offshore installations. Deliberate oil spills from ships in the open seas are often due to tank cleaning. Traditionally, such spills are monitored using surveillance aircrafts, but using a combination of satellite-based SAR images and aircrafts can cover larger areas. Manual detection of oil spills in SAR images is time consuming and not objective, as different human experts often will not report the same slicks. Automatic detection of oil spills can speed up the process considerably, and the detection gives objective and reproducible results.

The main objective of the project was the following: To fully exploit the potential for automatic detection of oil spills using new, advanced algorithms, and to demonstrate how well such a system will perform in terms of accuracy on a large set of SAR images both from the ERS satellite, ENVISAR and RADARSAT.
Sub-goals:
1. To study SAR imaging of oil spills and similarly looking oceanographic phenomena
2. To develop improved algorithms for dark spot detection
3. To develop improved algorithms for dark spot feature extraction
4. To develop improved algorithms for spot classification
5. To verify and demonstrate the algorithms on a large set of images

The project was organized in the following work packages: WP 1: Oil spill imaging, WP 2: Dark spot detection, WP3: Dark spot feature extraction, WP4: Spot classification, and WP5: Validation. The results are now briefly described for each WP.

WP1:Oil spill imaging.
The first subtask was to study in detail how oil spills dampen the surface waves, and how this can be imaged using different remote sensing sensors, both airborne and spaceborne. This work resulted in a review paper published in Remote Sensing of Environment (Brekke 2005a).

WP2: Dark spot detection.
An initial framework for oil spill detection consisting of preprocessing, dark spot detection, feature extraction and classification was presented in (Solberg 2007a). In the first major step, oil spills are segmented from the background because they appear darker than their surroundings. The segmentation algorithm presented in (Solberg 2007a) worked well in many cases, but in some cases failed for thin, linear oil spills. We thus developed an improved

segmentation algorithm that worked significantly better for thin, piecewise linear spills from moving ships. This was published in (Brekke 2006a, Brekke 2006b).

WP3: Feature extraction
After segmentation, all dark areas in the image have been identified. The next step is to distinguish between areas that are oil spills and other areas that have similar signature in SAR images (called oil spill "look-alikes"). A set of new features was derived and their performance compared to existing features (Solberg 2007a) and other features reported in the literature. The new features and their performance is described in (Brekke 2006a, 2006b).

WP4: Dark spot classification
After segmentation and feature extraction, the dark spots are classified as either oil spills or look-alikes based on a statistical model. An initial model, consisting of a statistical classifier combined with a rule-based approach was presented in (Solberg 2007a). The performance of this is also compared to other classifiers in (Brekke 2007a). In (Brekka 2007b) we show that the rule-based approach (which has some drawbacks in that it might not be too robust) can be replaced by an automatic confidence estimation step.

WP5: Validation.
By cooperation with the EU-project Oceanides, we got access to a large set of SAR images with oil spills and aircraft verification selected slicks. This was used to perform a benchmark study (Solberg 2007a) to compare manual detection to automatic detection and a semi-automatic detection. Results showed that automatic detection can produce comparable accuracy in detecting verified slicks compared to manual detection, and considerably faster than manual detection. Of the automatic algorithms tested, our performed the best. A further discussion of aircrafts vs. satellites for oil spill detection is found in (Solberg 2007b).

Relevance
The results produced in this project, and associated projects performed at the Norwegian Computing Center (where Anne Solberg has a part-time position), have resulted in a prototype automatic system for oil spill detection which is now currently installed at Kongsberg Satellite Station (KSAT) in Tromsø. KSAT has a manual service for operational oil spill detection, and the prototype is now being tested at KSAT. There is a potential that a combined manual/automatic approach will enable monitoring larger areas, because the manual inspection is significantly slower than automatic detection because the images are so large than the operator can only view a small part of the scene at a time. KSAT is one of the main providers of oil spill monitoring both for Norway and for Europe.

In addition to the scientific papers, the project has been presented in newspapers:

- Automatisk varsling av oljesøl, Yngve Vogt, Apollon, Desember 2006.
- Automatisk varling av oljesøk, Havneavisen, Desember 2006.

The project has resulted in the following publications:

(Brekke 2005a) C. Brekke and A. Solberg, Oil spill detection by satellite remote sensing, Remote Sensing of Environment, March 2005, vol. 95, no. 1, pp.1-13.

(Brekke 2005b) C. Brekke and A. Solberg, Feature extraction for oil spill detection based on SAR images, Proc. SCIA-05, June 2005, Joensuu, Finland, Lecture Notes in Computer Science, vol. 3540, pp. 75-84, 2005.

(Brekke 2005c) C. Brekke, Automatic detection of oil spills by SAR images – dark spot detection and feature extraction, FFI/Rapport-2005/00893.

(Brekke 2006a) C. Brekke and A. Solberg, Segmentation and feature extraction for oil spill detection in ENVISAT ASAR images, Submitted to International Journal of Remote Sensing, 2006.

(Brekke 2006b) C. Brekke and A. Solberg, Classification methods for oil spill detection in ENVISAT ASAR images, Proceedings, SPIE (636512), Image and Signal Processing for Remote Sensing, Stockholm, Sweden, Sept. 2005.

(Brekke 2007a) C. Brekke and A. Solberg. Classifiers and confidence estimation for oil spill detection in EVNISAR ASAR images, Accepted for publication in IEEE Geoscience and Remote Sensing Letters, 2007.

(Brekke 2007b) C. Brekke A. Solberg and G. Storvik, Classifying oil spills and look-alikes in ENVISAT ASAR images, In Proceedings of ENVISAT Symposium, Montreux, Switzerland, April 2007.

(Solberg 2004) A. Solberg, C. Brekke, R. Solberg and P. Husøy, Algorithms for oil spill detection in Radarsat and ENVISAT ASAR images, Procceding of IGARSS.04, Anchorage, Alaska, pp. 4909-4912.

(Solberg 2007) A. Solberg, C. Brekke and P. Husøy, Oil spill detection in Radarsat and Envisat SAR images, IEEE Tr. Geoscience and Remote Sensing, vol. 45, no. 3, pp.746-755, 2007.

A. Solberg and C. Brekke, Oil spill detection in northern European waters: approaches and algorithms, in Remote Sensing of the European Waters (ed. V. Barale and M. Gade), In press, Springer Science and Business Media, 2007.