Abstract

SAR images display a characteristic intensity variation along the range dimension, caused by the fact that the backscattered intensities depend on the incidence angle. In the case of wide-swath images, this intensity variation from near range to far range is significant enough to affect image segmentation performed on absolute intensity values. The effects are an over-segmentation which creates banding in the range direction, as well as the dilution of the real class distinction. In addition, the decay rates vary for different classes, thus reducing the efficiency of previously proposed global-correction methods.

We propose an unsupervised segmentation method that incorporates the incidence-angle variation into the standard mixture modeling. We demonstrate its efficiency on UAVSAR images containing oil spills and ships on an open-water background, acquired in the North Sea during 2015 (the NORSE2015 experiment). By considering the intensities of the HH channel and an incidence angle range spanning from 30 to 60 degrees, the proposed algorithm is able to remove the banding effect and to segment the main image structures (water, oil slicks and ships) into distinct classes, thus showing the importance of accounting for the incidence angle.

Model

The log-intensities are modeled as a mixture distribution, maintaining the same principles as previously developed segmentation algorithms for SAR data [1]. The mixture components (classes) are assumed to be Gaussian along constant incidence-angle azimuth lines, with mean values expressed as a linear function of the given incidence angle [2]: \( a_k + b_k \theta \). Each class is therefore defined by a triplet of parameters: covariance \( \Sigma_k \), slope \( b_k \) and intercept \( a_k \). After including the class weights \( \alpha_k \), the model becomes:

\[
\begin{align*}
P(X|\Theta) &= \sum_{k=1}^{N} \alpha_k \frac{1}{(2\pi)^{n/2}|\Sigma_k|^{1/2}} \exp\left(-\frac{1}{2}(x-a_k-b_k\theta)/\Sigma_k(x-a_k-b_k\theta)^T\Sigma_k^{-1}(x-a_k-b_k\theta)\right) \\
\end{align*}
\]

Once the posterior probabilities (membership weights) \( \alpha_k \) are computed, the class parameters are estimated using Expectation-Maximization equations, i.e.:

\[
\begin{align*}
a_k &= \sum_{n=1}^{N} x_n \delta_n \sum_{i=1}^{K} \alpha_i \theta_i / \sum_{i=1}^{K} \alpha_i \theta_i \\
b_k &= \sum_{n=1}^{N} x_n \delta_n \sum_{i=1}^{K} \alpha_i \theta_i^2 / \sum_{i=1}^{K} \alpha_i \theta_i^2 \\
\Sigma_k &= \sum_{n=1}^{N} x_n \delta_n (x_n - (a_k + b_k \theta_n))(x_n - (a_k + b_k \theta_n))^T / \sum_{n=1}^{N} \delta_n
\end{align*}
\]

Segmentation of UAVSAR data

The incidence-angle dependency of the measurements collected from the UAVSAR platform was analyzed for all 4 polarimetric channels, by manually selecting a homogenous open-water area. Prior to analysis and segmentation a 15x60 multilook window was applied.

Conclusions

Incorporating the incidence-angle effect in the automatic segmentation of SAR images successfully connects areas of the same class that are spread throughout the range. Potential improvements:

- The simple, approximative incidence-angle relation can be modified to account for non-linear variations, as well as the near-range behavior of wide-swath instruments such as the UAVSAR.
- The Gaussian distribution can be replaced with a model that accounts for heavy tails or texture.
- Extensions for polarimetry are worth further exploration, provided that the different incidence-angle dependent behaviors can be accurately modeled for each channel/feature.

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References