FUSION OF SYNTHETIC APERTURE RADAR AND HYPERSPECTRAL IMAGERY TO DETECT IMPACTS OF OIL SPILL IN GULF OF MEXICO

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ABSTRACT

- The Deepwater Horizon blowout in the Gulf of Mexico resulted in one of the largest accidental oil disasters in U.S. history.
- More than 200 million gallons of oil spewed into the Gulf of Mexico and the petroleum hydrocarbons were released from the reservoir through the wellbore for 87 days causing an oil spill of national significance.
- The oil spill caused significant damage to the environment and to the marine habitats
- The damages associated with the oil spill include oiled and dead wildlife, polluted marshes, and lifeless deep water corals.
- The main objective of this research is to apply fusion techniques on polarimetric radar and hyperspectral imagery to investigate the benefit of fusion for improved classification of coastal vegetation contaminated by oil.
- In this approach, fusion is implemented at the pixel level by concatenating the hyperspectral data with the high resolution SAR data and analyze the fused data with Support Vector Machine (SVM) classification algorithm.

STUDY AREA AND DATA USED

- The study area is near Wilkinson Bay, Louisiana, which was heavily impacted by oil.
- The coastal areas affected by Deepwater Horizon oil spill as of 19th June 2010 is shown in Figure 1.
- In this study, we use the L-band quad-polarized radar data acquired by Unmanned Aerial Vehicle Synthetic Aperture Radar (UAVSAR) and Hyperspectral Imagery (HSI) from the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) optical sensor.

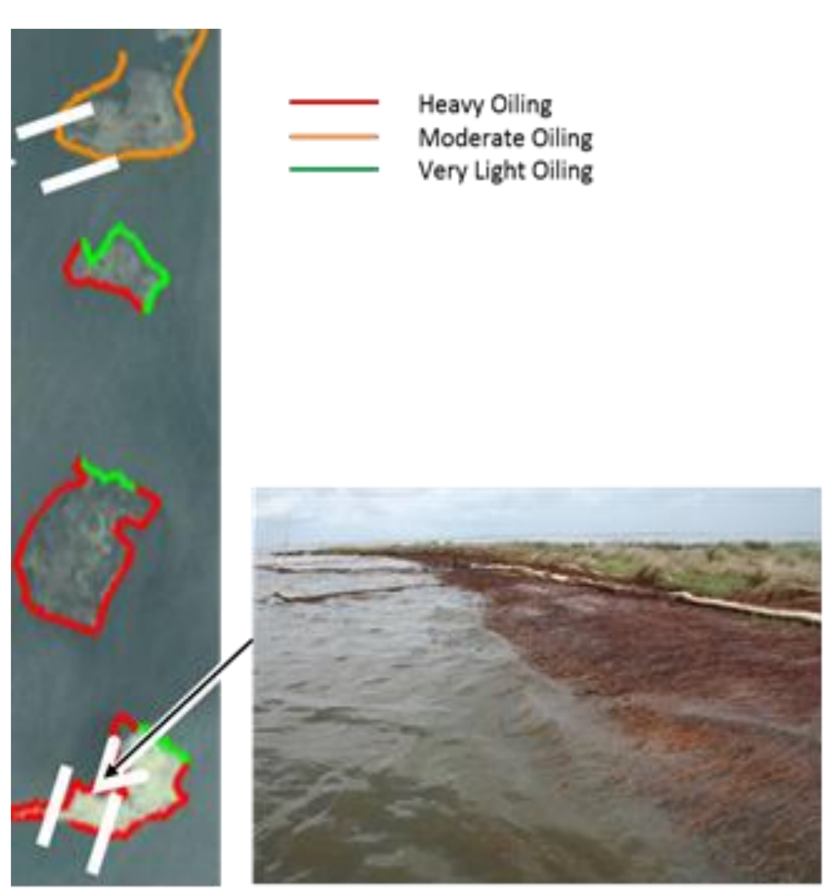

Figure 1: Field photo of oiled and dead vegetation near Wilkinson Bay, Louisiana

- L-band UAVSAR data collected on June 23, 2010 with a spatial resolution of 1.85 m and AVIRIS data collected on July 31, 2010 with a spatial resolution of 9.57 m were used in this study.
- The NASA AVIRIS is a 224 channel hyperspectral instrument with spectral coverage from 400 – 2500 nanometers (nm).
- The size of SAR subset is 1316 x 402 pixels and the size of HSI subset is 284 x 83 pixels.

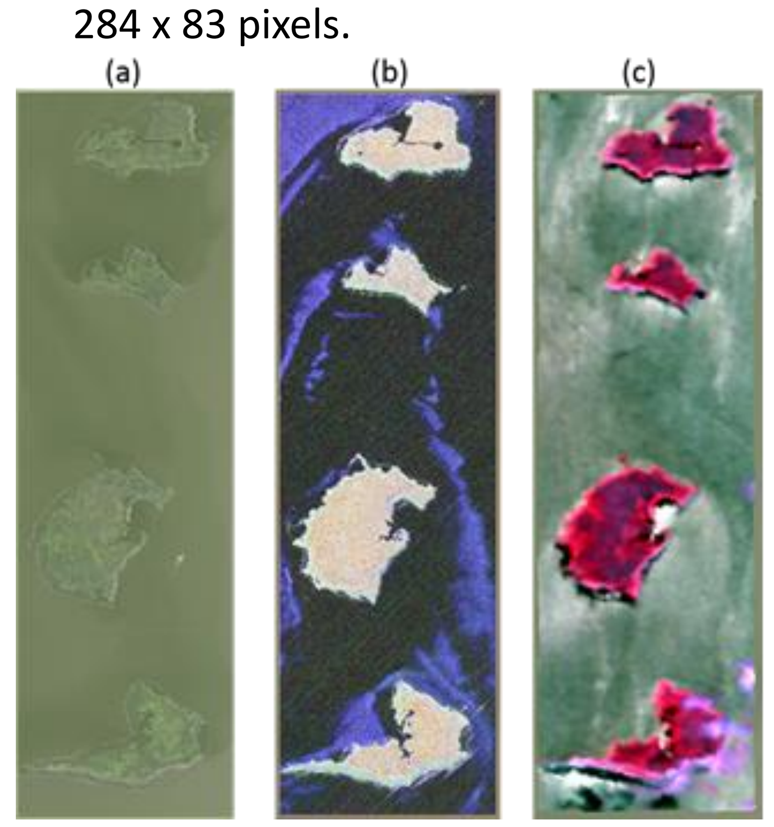

Figure 2: (a) Optical image of the study area, (b) Color composite of UAVSAR 3-band (HH, HV, and VV) image subset, and (c) Color composite of AVIRIS image subset

DATA FUSION

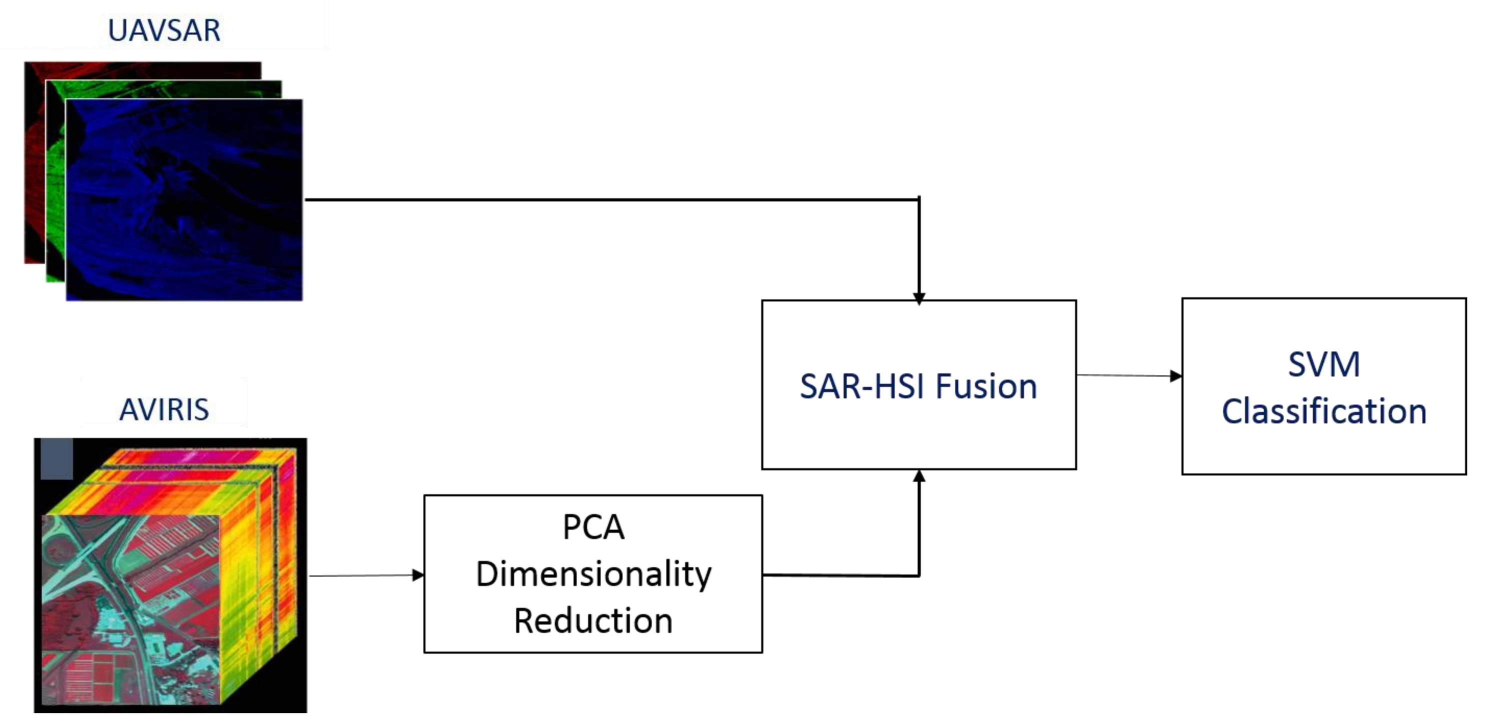

Figure 3: Block diagram of pixel level fusion of SAR and hyperspectral imagery

- Pixel level fusion was implemented on SAR and HSI data and Figure 3 shows the block diagram of the approach
- The downsampled SAR data were generated by taking the median of a 5 x 5 spatial window and concatenated with the HSI data
- SVM classifier was implemented on the fused HSI-SAR dataset and on the extracted feature sets of individual sensors

FEATURE EXTRACTION

- Principal Component Analysis (PCA) was applied to achieve dimensionality reduction on hyperspectral data
- Grey Level Co-Occurrence Matrix (GLCM) features were extracted from the SAR data in four spatial orientations: horizontal, left diagonal, vertical, and right diagonal corresponding to 0°, 45°, 90°, and 135°, and six features have been computed with a window size of 11 x 11
- The features used in this study are: energy, correlation, variance, homogeneity, entropy, and inertia

CLASSIFICATION

- The SAR and HSI images were co-registered and six ground truth classes were defined for investigation
- The ground truth classes and the number of pixels in each class for SAR and HSI data are given in Table 1

Table 1: Ground Truth Classes

Class Label	Name of class	Number of HSI Pixels	Number of SAR Pixels
C1	Vegetation with heavy oiling	32	398
C2	Vegetation with very light oiling	15	194
C3	Water	77	2161
C4	Water with oil	161	4119
C5	Healthy Vegetation	20	452
C6	Vegetation with moderate oiling	13	97

CLASSIFICATION

- The SVM classifier was tested with five different combinations of features derived from the HSI and SAR data as shown in Table 2

Table 2. Feature Combinations

SAR	HH, HV, and VV backscatter magnitudes (3 features)
SAR – GLCM	SAR with 36 GLCM features
HSI	224 HSI channels
HSI – PCA	5 HSI principal components
HSI – SAR Fusion	3 SAR bands (HH, HV, and VV) with 5 HSI principal components

RESULTS AND DISCUSSION

The accuracy results for each of the feature combinations is shown in Figure 4

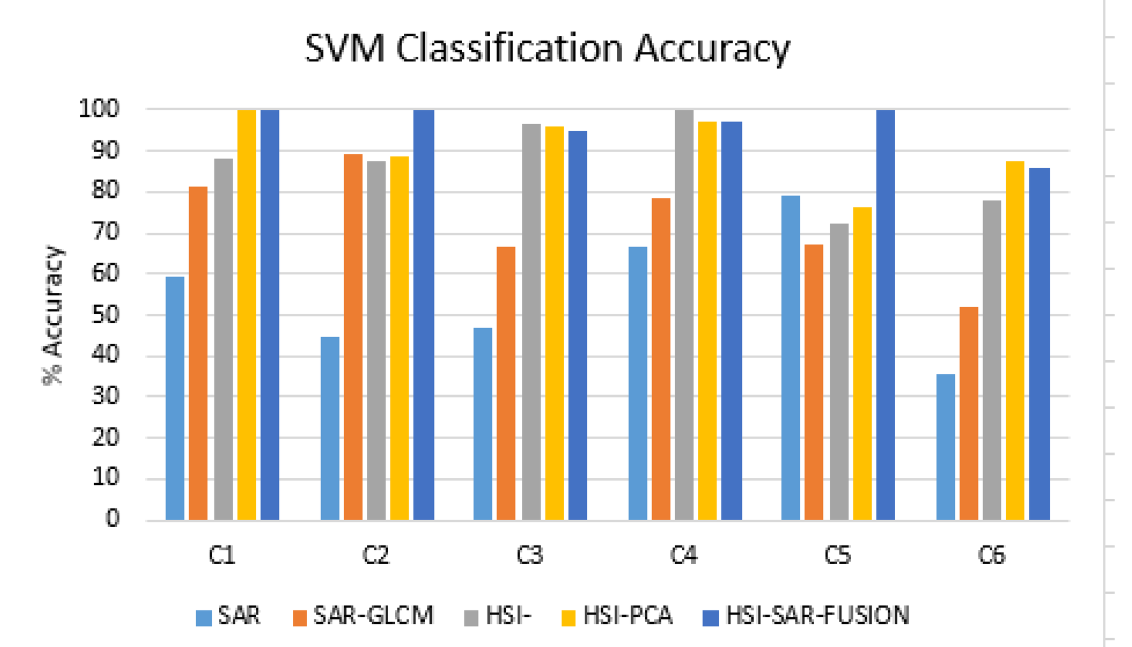

Figure 4: Classification accuracy (%) of SVM classifier with SAR polarization data (HH, HV, and VV bands), SAR with GLCM features, HSI without dimensionality reduction, HSI with PCA, and HSI-SAR fused data

- The SAR-based features performed better on two classes: healthy vegetation (C5) and lightly oiled vegetation (C2)
- For all the other classes, the HSI-based features outperformed
- Overall, the HSI-SAR fusion performed as well as or better than the other combinations

CONCLUSION

In this study, fusion of SAR and HSI data was implemented at the pixel level for classification of areas affected by the oil spill in the Gulf of Mexico. Five different combinations of features derived from the HSI and SAR data were tested with SVM classifier. The results demonstrated the benefit of multi-sensor fusion with overall accuracy of the fused feature set exceeding that of either HSI or SAR alone.

ACKNOWLEDGEMENTS

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