Object-oriented Image Classification for Benthic Habitats Using Multispectral Quickbird Data

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Introduction

• Critical need to monitor the conditions of the corals.

• Remote Sensing: an effective tool for mapping coral reef habitats.

• Supervised and unsupervised methods: only per-pixel spectral information is utilized.

• Objective: introduce object-oriented method for benthic habitats classification.
Image classification methods

• Visual interpretation
  Habitats are identified visually by an analyst based on experience, then delineated and labeled manually, labor intensive, inevitable inconsistency, lacks the detail.

• Multispectral classification of image data
  - Supervised
  - Unsupervised

• Object-Oriented Image segmentation
  Classifies image objects or segments instead of individual pixels
Case Study- North Sound, Antigua

- North Sound of Antigua Island, located in the eastern arc of the Leeward Islands.
- Extensive coral sand beaches with relatively shallow off-shore waters.
- Coral species include Montastrea, Diploria, Cropora, Porites and Acropora.
Data

- Quickbird multi-spectral remote sensed imagery acquired on 12/03/2005.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Type</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.61-meter</td>
<td>Panchromatic</td>
<td>0.45 – 0.90 µm</td>
</tr>
<tr>
<td>Black-and-white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4-meter</td>
<td>Band 1 (Blue)</td>
<td>0.45 – 0.52 µm</td>
</tr>
<tr>
<td>Multispectral</td>
<td>Band 2 (Green)</td>
<td>0.52 – 0.60 µm</td>
</tr>
<tr>
<td></td>
<td>Band 3 (Red)</td>
<td>0.63 – 0.69 µm</td>
</tr>
<tr>
<td></td>
<td>Band 4 (NIR)</td>
<td>0.76 – 0.90 µm</td>
</tr>
</tbody>
</table>
Data Pre-processing

- **Geometric Corrections**: RPC provided along with the image by Digital Globe, Inc.
- **Land and Cloud Masking**: NIR band
- **Atmospheric Correction**: follows Mishra et al., 2006.

\[
L_t(\lambda_i) = L_r(\lambda_i) + L_a(\lambda_i) + T(\lambda_i)L_g(\lambda_i) + t(\lambda_i)L_w(\lambda_i)
\]

- **Rayleigh path radiance** \(L_r(\lambda_i)\): computed and applied to the image using the algorithm developed by Gordon and Clark (1981).
- **Aerosol scattering** \(L_a(\lambda_i)\): derived by subtracting the Rayleigh path radiance from TOA radiance in deep water pixels of the NIR band.
- **Diffuse transmittance** \(t(\lambda_i)\): computed as recommended by Gordon et al. (1983).
Atmospheric Correction

\[ L_t(\lambda_i) = L_r(\lambda_i) + L_a(\lambda_i) + T(\lambda_i)L_g(\lambda_i) + t(\lambda_i)L_w(\lambda_i) \]

**Rayleigh scattering**

\[ L_r(\lambda, \theta) = F'_s(\lambda)P_r(\alpha)\tau_r(\lambda) / 4\pi \cos \theta \]

**Aerosol scattering**

**Diffuse transmittance**

\[ t(\lambda, \theta) = \exp\left(\left[-\tau_r(\lambda) / 2 + \tau_{oz}\right] \sec \theta\right) \]

\[ F'_s = F_s(\lambda) \exp\left[-\tau_{oz}(\sec \theta + \sec \theta_s)\right] \]

\[ P_r(\alpha) = \frac{3}{4}(1 + \cos \alpha^2) \]

\[ \tau_r(\lambda) = \tau_{r0}(P / P_0) \]

\[ \tau_{r0} = 0.0089\lambda^{-4}(1 + 0.0113\lambda^{-2} + 0.00013\lambda^{-4}) \]

\[ \theta : \text{Satellite zenith angle} \]

\[ \theta_s : \text{Solar zenith angle} \]

\[ \alpha : \text{Scattering angle relative to the forward direction} \]

\[ \tau_{oz} : \text{Optical thickness of the ozone layer} \]

\[ P : \text{Air pressure} \]

\[ P_0 : \text{Standard Surface atmospheric pressure} \]

\[ F_s(\lambda) : \text{Solar radiance at the top of atmosphere} \]

\[ \lambda : \text{Wavelength} \]

<table>
<thead>
<tr>
<th></th>
<th>Rayleigh</th>
<th>Diffuse transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>1.775</td>
<td>0.9235</td>
</tr>
<tr>
<td>Green</td>
<td>1.066</td>
<td>0.9608</td>
</tr>
<tr>
<td>Red</td>
<td>0.3398</td>
<td>0.9842</td>
</tr>
<tr>
<td>NIR</td>
<td>0.2165</td>
<td>0.9994</td>
</tr>
</tbody>
</table>
Atmospheric Correction

• Trick for extracting TOA radiance in deep water pixels of the NIR band
  Select a group of pixels to represent deep water, calculate the mean and standard deviation of radiance, **subtract two standard deviations from the mean** to account for sensor noise.

Geometrically corrected image  
Land and clouds masked image  
Atmospherically corrected image

All images are linearly stretched
Water Column Correction

Depth-invariant bottom index $x_{ij} = \ln(L_i) - \left[\frac{k_i}{k_j} \cdot \ln(L_j)\right]$
Result-
Unsupervised classification

- Software: ENVI, ISODATA functionality
- Combine classes after classification.
- Classes: coral, sand, mixed-coral and sand, sandy mud, muddy sand, mangroves.
Object-oriented classification

- Software: Definiens(eCognition)
Result- Segment
Result- Classification
Unsupervised vs O-O
Conclusion

• Atmosphere correction and water depth compensation is critical for benthic habitat classification.
• Objective Oriented method can provides a better way for the classification of benthic habitats by incorporating contexture information.
Further study

- More classes
- Validation
- Incorporate texture information.
- Incorporate shape information: linear reefs vs patch and pinnacle reefs.
- Consider the relationship between objects: grouping image objects.
Thank You

Questions