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5A Remote sensing of reef environments

Spectral discrimination of coral species and habitats in Hong Kong

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Abstract. Four spectra of coral species in the genera *Acropora*, *Goniopora*, *Pavona* and *Platygyra*, and coral habitats, sand and rock, were collected in the field and laboratory. The pure coral spectra show two reflectance peaks at ~600nm and ~650nm, and less distinctive peaks between 470nm-520nm whereas that of coral habitat show gentle slopes with shoulders at ~630 nm for rock and ~650 nm for sand. The reflectance spectra of coral species and habitats on the substratum drop dramatically at 565nm in local waters. The two distinctive spectral peaks of coral species and coral habitats are much less discriminative underwater. These results indicate a significant water column effect even in the region of good water quality in Hong Kong. Classification of sand and rock at the land surface showed that Landsat 7 is more effective than SPOT 5 in mapping coral habitats.

Key words: multispectral, SPOT 5, Landsat 7, supervised classification, coral spectra

Introduction

The spatial resolution, spectral resolution and the effectiveness of water column corrections are crucial to mapping coral communities in Hong Kong using satellite remote sensing techniques. Satellite imageries at high spatial resolution are good assessment tools due to the small geographical scale of local coral communities. Mathematical models comprising the key components and water quality parameters, help to retrieve appropriate reflectance for subsequent classification. The spectral characteristics in the visible range, in terms of bandwidth and number of bands, are the determinants to target discrimination in the requisite classification.

In the previous stage of this study, imagery-derived spectra were used for retrieving potential coral pixels. Subsequently, the target spectral signatures were collected. The spectral discrimination of coral species and coral habitats were described in detail in another document. Based on the conclusion of spectral discrimination, this paper briefly investigates the impact of three determining parameters in remote sensing of local coral communities: 1) the effectiveness of simple water column correction, 2) the effectiveness of spectral bands in SPOT 5 and Landsat 7 using Spectral Angle Mapper, and 3) the effectiveness of subpixel analysis using Mixture-tuned Matched Filtering.

This study used SPOT 5 and Landsat 7 imagery because they are the available resources so far. In the future, WorldView 2 (with additional bands, particularly the yellow band in the visible range), QuickBird and IKONOS (with high spatial resolution) derived imagery are also suggested as options.

Material and Methods

Data collection

According to the bottom profiles of local coral areas, three main classes are found, they include sand, stratified rock and corals. Four common/massive coral species, *Acropora* sp., *Goniopora* sp., *Platygyra* sp. and *Pavona* sp. were chosen in the study site, Tung Ping Chau at the easternmost of Hong Kong waters. The pure spectra of the four coral species, rock and sand were collected in both the first test field trip and at the Marine Science Laboratory (MSL), Chinese University of Hong Kong (CUHK).

At least 30 spectral data in the reflectance unit were acquired for each pure target. The spectrometer (ASD FieldSpec Handheld, spectral range from 275nm-1081nm and bandwidth 1.577nm) with 7.5 degree foreoptics was slightly displaced for every 10 spectra in order to capture the target heterogeneity. In the laboratory, the spectrometer with foreoptics was held 15 cm above the corals, which were lifted to the tank surface, in order to restrict the field-of-view on the targets to ~2 cm in diameter such that the background interference was avoided. In the field, the spectrometer with foreoptics was held 1 meter above sea surface in order to restrict the field-of-view on the substratum to no more than 65 cm in diameter, and reduce the influence of water surface reflection. Extensive coral masses were selected in order to compensate for the inaccurate and non-vertical positioning of the spectrometer towards the underwater targets caused by the wavy sea surface. Divers released buoys to indicate the target locations, and a group of three individuals fixed the position of the spectrometer and recorded the data. The field and laboratory measurements were made on separate days, 25 May and 24 July 2011 respectively.

The best time for data collection was found to be between 10:00 – 14:00, excluding high noon at around 11:30 a.m. - 1:30 p.m. when the spectrometer shadows affect the target measurements.

Data processing

The SPOT5 imagery and Landsat 7 imagery were acquired on 2 Nov 2003 and 28 Aug 2002. They were preprocessed from digital values to reflectance. Lacking water column corrections, the pixels in submerged zones were not analysed.

For the spectral effect, in both SPOT 5 and Landsat 7, the pixels on land surface along the coastline were classified to sand and rock using the supervised classification method, Spectral Angle Mapper (SAM). In SAM, each pixel and each reference target are represented by an n-dimensional vector, in which the number of dimensions is equal to the number of bands. The spectral angle between the two spectra determines the similarity. The smaller spectral angle represents higher similarity. The length of the vectors does not affect the classification results, hence, it is insensitive to reflectance level. The accuracy or the success rate of the classified SPOT 5 and Landsat 7 imageries were compared.

For the spatial effect, the subpixel method adopted the Mixture-tuned Matched Filtering (MTMF) which estimates the proportion of specified (not all) known pure targets in each pixel. Bands with high noise were not used in the processing. The Matched Filtering (MF) scores estimate the abundance of the known spectra and relative degree of match. 1.0 is the perfect match. The infeasibility values show the noise sigma units and low infeasibility values represent mapped pixels with high feasibility of the MF result. Pixels with MF values higher than zero and infeasibility values less than 2 were selected to be the best classified pixels in the 2D scatter plot. The range of the MF scores and the selected mapped pixels are compared.

Results

Spectral distinctiveness of coral species and coral habitats

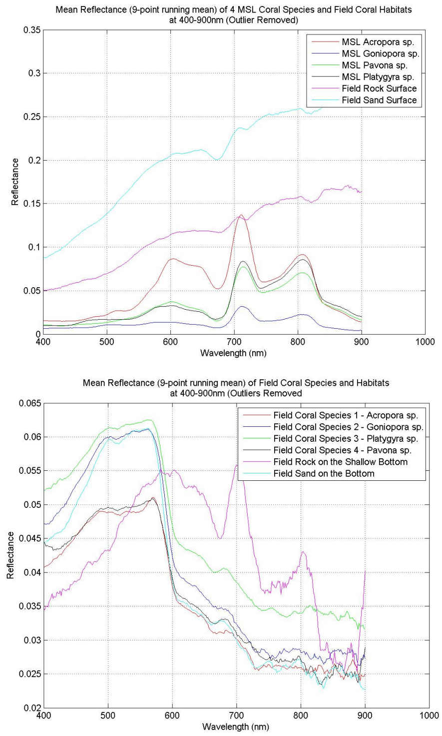

Figure 1: The reflectance spectra of corals species and habitats a) on water surface and b) underwater.

The mean spectral reflectance collected at the water surface of coral species generally shows two distinctive shoulders in reflectance at ~600 nm and ~650 nm and a small peak between 470 nm-520 nm in the visible range (Fig.1a). Coral habitats show gentle slopes with shoulders at ~630 nm for rock and ~650 nm for sand. Sand has an overall higher magnitude of reflectance than rock. By both Wilcoxon rank sum test and t-test, it is found that the reflectance spectra of all coral species were statistically different from sand and three of them are similar to rock to some extent. *Acropora* sp. shows the most distinctive features among all coral species. Both *Pavona* sp. and *Platygyra* sp. are similar to each other.

In the field, all spectra of coral species and sand bottom are abruptly attenuated from 570nm-605nm and reach the low level from 720nm onwards (Fig. 1b). These data indicate that the distinctive shoulders of the target spectra at 600nm and 650 nm are much dissipated in local waters. The rock spectra were collected in very shallow water in the field, therefore its spectrum might not fully represent the underwater situation. The field measurement method will be refined and measurement tools will be improved following the next field trips.

The distinctive shoulders of reflectance spectra at 600nm and 650nm are much reduced when they were resampled to SPOT 5 and Landsat 7 spectral resolution (Fig.2). The small peaks of reflectance spectra from 480nm -520nm were also reduced in Landsat 7 resampled spectra and they were totally lost in SPOT 5 due to the unavailable bands at less than 500nm.

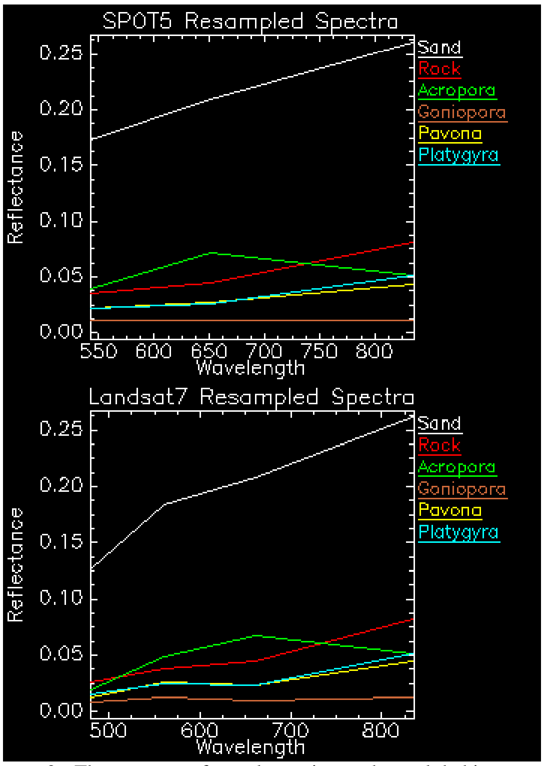

Figure 2: The spectra of coral species and coral habitats are resampled to a) SPOT 5 and b) Landsat 7 spectral resolution.

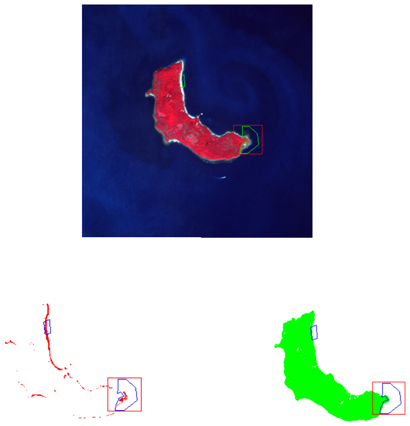

Figure 3: In SPOT 5 imagery, a) false colour using G, R NIR bands, b) sand pixels in red were classified at 0.24 SAM maximum threshold with acceptable accuracy and c) rock pixels in green were classified at 0.3 SAM maximum threshold with serious confusion with terrestrial vegetation

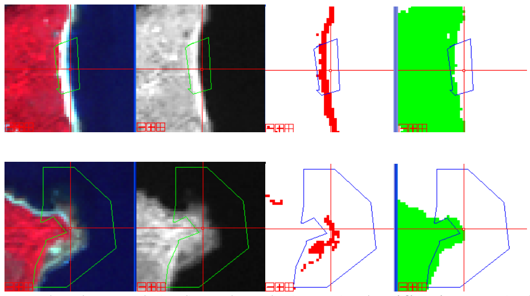

Figure 4: The sand (red) and rock (green) classification at a) the upper area and b) the lower area in SPOT 5. The NIR imagery shows the exposed area (white) and submerged area (black) on the shoreline.

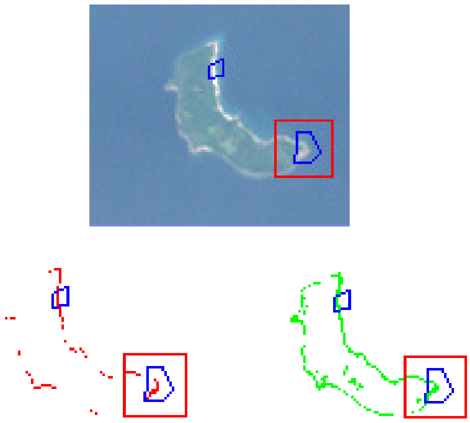

Figure 5: In Landsat 7 imagery, a) true colour using B, G, R bands, b) sand pixels in red are classified at 0.2 SAM maximum threshold with acceptable accuracy and c) rock pixels in green are classified at 0.21 SAM maximum threshold. Both showed acceptable accuracy by visual assessment and the confusion between sand and rock pixels existed but was not serious.

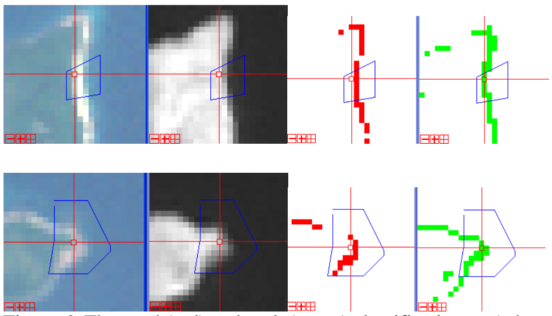

Figure 6: The sand (red) and rock (green) classification at a) the upper area and b) the lower area in Landsat 7. The NIR imagery showed the exposed area (white) and submerged area (black) on the shoreline.

Discussion

Water Column Effect

For the water column effect, neither target spectra nor pixel spectra were processed using models, such as the semi-analytical model, SAMBUCA. In the previous stage of this study, a simple water correction was carried out in SPOT 5 imagery using the Lygenza equation (1978) which had the assumption of clear water and homogeneous habitats. Depth invariant indexes were derived from the two band pairs, green/red and green/NIR for unsupervised classification in the submerged zone. No class representing potential corals existence was shown. Since the accurate locations of coral types and habitats are not available, the water corrected imagery cannot be further processed using supervised classification. It was found that the band combination is restricted by the three available bands. Strictly speaking, NIR is not desirable for deriving the ratio. Such attempts showed that more band pairs and more visible bands are required (Huen & Zhang 2011). In the next step of this study, semi-analytical models will be applied to tackle the water column effect.

Spectral effect

Excluding the submerged zone due to no water column correction, two land areas were selected in the imagery for examining the classification results. The target spectra were resampled to SPOT 5 and Landsat 7 resolution. The upper area of the island is sandy beach whereas the lower one is the shore mixed with sand and rock. Three bands (G, R and NIR) in SPOT 5 and four bands (B, G, R and NIR) in Landsat 7 were selected for SAM classification. For SPOT 5 imagery, in the upper area, sand pixels were classified accurately whereas rock pixels were misclassified to vegetation. In the lower area, the sandy portion of the shore was classified satisfactorily to sand class by visual assessment. Rock pixels were not detectable in SPOT 5 (Fig. 3&4). For Landsat 7 imagery, in the upper area, the sand pixels were classified satisfactorily whereas rock pixels were misclassified in the submerged zone. In the lower area, both sand and rock pixels were classified satisfactorily with some pixel confusion between the two classes (Fig.5&6). Generally, Landsat 7 gave a better classification result than SPOT 5. Although sand spectra have higher magnitude than rock spectra, SAM is insensitive to the level of reflectance. Their distinctiveness showed at the shoulders at ~650nm in sand and ~630nm in rock. The bandwidth/band-range and band numbers of Landsat 7 and SPOT 5 in the visible range may attribute to the difference in the classification results.

Spatial effect

The subpixel analysis, MTMF, was applied to Landsat 7 (with three selected bands of B, G and R) of and SPOT 5 (with three selected bands of G,R and NIR). In the lower area, where the shore was mixed with sand and rock, it is found to be infeasible to classify both Landsat 7 and SPOT 5 in subpixel analysis. For the MF scores (represents the relative degree of match and spectra abundance) under the infeasibility value of 2, they range from 0 - 0.25 for sand and 0 – 0.2 for rock in SPOT 5 whereas they range around zero for both sand and rock in Landsat 7. It indicated that subpixel analysis was not feasible in Landsat 7 shown by the MF scores near zero, and also not feasible in SPOT 5, which had no classified pixels in the shore region. The small geographical scales of rock and sand on land surface in the study island are somehow comparable to that of coral habitat in the submerged zone. Hong Kong coral communities are very small, with sizes usually ranging from a few meters to only tens of meters wide from the shore, up to a depth of 5 meter or less (Ang *at el*. 2005). The infeasible classification at subpixel in both SPOT 5 and Landsat 7 may reflect the appropriateness of the selected method or the types of satellite imagery. MTMF is developed for hyperspectral analysis and it is also applicable to multispectral analysis but the results cannot be comparable to that of hyperspectral data.

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