Detection of Small Shallow-water Coral Reefs on Landsat Imagery

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Abstract: Large number of coral reefs in Thailand waters make the use of satellite imagery probably the only practical method fo r their monitoring. This paper reports the result of detecting small shallow-water coral reef by using maximum likelihood classification technique. Combination of blue/green and near-infrared band ratio are used as spectral signatures derived from a Landsat 7 imagery covering western portion of the Gulf of Thailand. Result assessment reveals accuracy significantly over 60 percent. The result is encouraging and would be a basis for further study to realize the full potential and limitation of this technique.
Keywords: Landsat 7 Imagery, Coral Reef, Classification, Band Ratio.

1. Introduction

Thailand has more than 400 coral reefs and this research is an attempt to detect small shallow reefs which comprise most of them. As one of the most important natural resources which have long been exploited by fishing and tourism, it is essential that they are monitored on regular basis. The large number of the reefs coupled with the fact the majority of them are scattered along the long coast line make the use of satellite imagery probably the only practical method for such task.

The first step of monitoring is detection. The shallow-water type of the reefs in the Gulf of Thailand are no deeper than 8 m, making it theoretically detectable by blue and green band of Landsat imagery. The detection effort, however, is complicated by two problems: 1) water in the gulf is not very clear and so significantly reduce the penetration depth of blue and green light, 2) the small size of the reefs comparing with the spatial resolution of Landsat imagery. Using higher-resolution satellite imageries such as SPOT 5 or Ikonos may alleviate the latter problem but the higher prices of the data also make the technique much less justifiable economically. Aerial photography provides even higher resolution data but in this case it is the least attractive choice due to very expensive initial cost and high mobilization cost to take photograph over scattered islands. Their use should be limited to the places where coral reefs cannot be identified on lower resolution but also much lower-priced imageries such as those from Landsat 7.

The aim of this study is to apply the simple and well-known maximum likelihood method on Landsat imagery and to assess the merits and limitations of the technique. Details are in subsequent sections.

2. Description of the Study Area

Kai island, around 5 km off Chumporn which is a southern province of Thailand, has been selected as a test site. The island is part of Chumporn archipelago national park and is under the risk of environmental and ecological damages due to rising popularity of diving tourism in this area.

The largest part of Kai reef is on the west and south. The reef is around 5 m deep and around 100 – 200 m wide. Data from [1] indicates that many reef types are found though mostly are encrusting form.

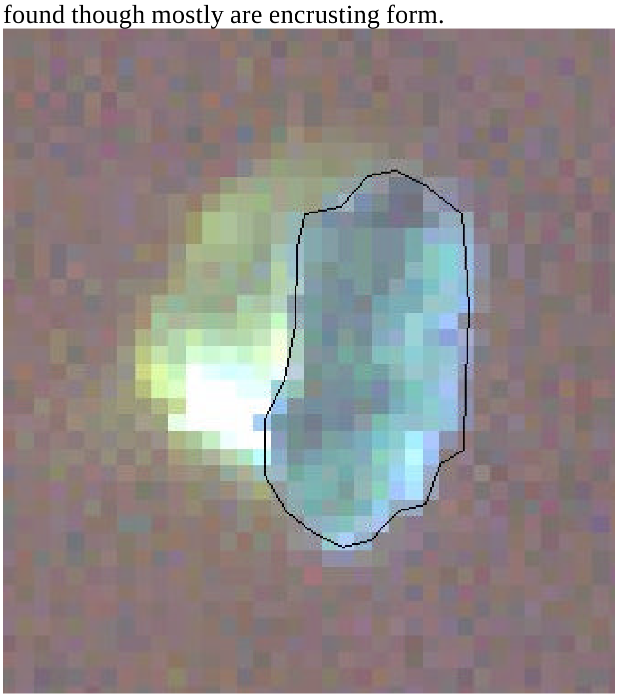

Fig. 1. Landsat 7 image of the study area of Kai island. The island is demarcated by black line.

The Landsat 7 image used in this study was taken on 5 December 2001. The Kai island is shown in figure 1. Different underwater features can be clearly seen on the image. DN readings over different areas showed that these marine features are separable numerically and so statistical classification like maximum likelihood should yield high accuracy once performed subsequently.

3. Preprocessing

The obtained Landsat 7 imagery is level 1G, a standard product whose 1 sigma positional accuracy is 250 m [2]. This translates to an uncertainty of about 8 pixels on image. While this might be sufficient for large area classification task, it is not accurate enough for the purpose of this study considering that reef size is within the range of only a few pixels. A second degree polynomial transformation has been used in correcting the positional biases in the obtained image. The coordinates of 12 ground control points (GCP) has been measured by precise point positioning technique (PSPP) as described in [3]. The overall RMS error is 0.32 pixel or around 10 m on the ground. The positional reading of the image would now have roughly the same accuracy as those obtained from GPS and would facilitate the field survey.

Apart from the geometric correction described above, the image has not been processed for any radiometric corrections. The water column correction described in [4], essential for most other marine feature detection, is bypassed due to the fact that each coral reefs under study is only few-meter deep as is the depth variation.

4. Field Survey

Field survey to gather ground truth took place between 1 – 5 May 2003. Handheld GPS with waterproof plastic bag was used to measure UTM coordinates of 124 points which will be served as ground truth. The majority of these points had been pre-selected but many of them were determined on spot. Figure 2 shows the distribution of ground truth positions.

Data from field survey has been analysed with the DN readings obtained previously. It is concluded to designate three classes of underwater objects around Kai island namely 1) reef, 2) sand and 3) debris of reef and stones.

The most problematic feature is the reef which is the main interest of this research. Though different types of reef exist, their spectral signatures are indistinguishable. All initial attempts to separate each type into different class failed. The failure due mainly to the fact that each type does not occupy area large enough to dominate the radiometric characteristic of pixels and so their signatures do not stand out from the others. Eventually all types have to be clumped into the same class. This problem reveals the limitation of using relatively low resolution Landsat 7 imagery.

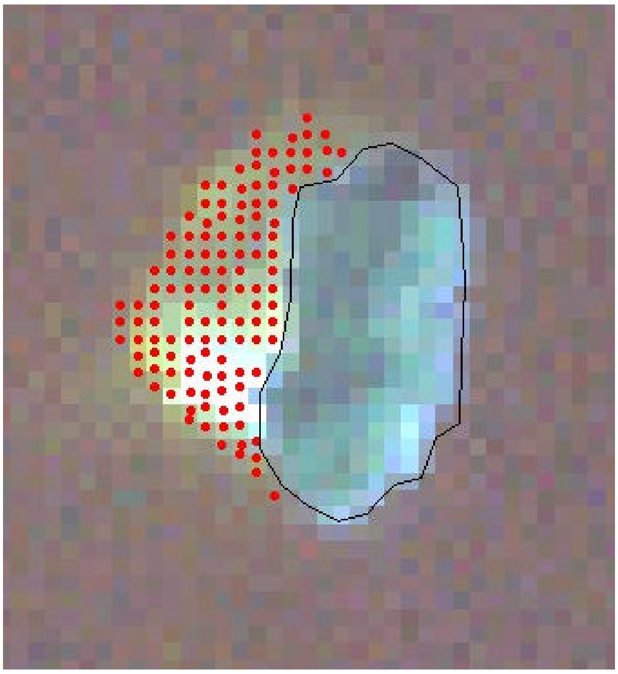

Fig. 2. Distribution of ground survey points over the coral reef area of Kai island.

The 124 field survey points are divided into two categories. The first group comprises 44 points are used for creating spectral signatures. The remaining 80 points which are exclusively kept for testing the result of classification.

5. Coral Reef Detection

Maximum likelihood classification technique using combination of band 1 (blue), band 2 (green) and band 4 (near-infrared) yields accurate result, as shown in table 1 below.

Apart from using direct DN values in the image to create spectral signature, two other alternatives are explored. The first one is to replace the band 4 with a composite band created from ratio of DN value between band 4 and band 2. More accurate result is obtained from this alternative as shown in table 2 that improvement occurs in every class.

Table 1. Error matrix of Kai island classification using spectral signature derived form band 1, 2 and 4.

Feature	Reef	Sand	Debris	Total	Acc.
Reef	35	15	2	52	67.3
Sand	5	13	2	20	65.0
Debris	2	3	3	8	37.5
Total	42	31	7	80	63.8

Table 2. Error matrix of Kai island classification using spectral signature derived form band 1, 2 and 2/4.

Feature	Reef	Sand	Debris	Total	Acc.
Reef	41	11	0	52	78.8
Sand	3	15	2	20	75.0
Debris	1	3	4	8	50.0
Total	45	29	6	80	75.0

Table 3. Error matrix of Kai island classification using spectral signature derived form pca .

Feature	Reef	Sand	Debris	Total	Acc.
Reef	42	10	0	52	80.8
Sand	2	16	2	20	80.0
Debris	0	2	6	8	75.0
Total	44	28	8	80	80.0

Another classification alternative is to firstly use principal component analysis (pca) technique to transform the original 6-band (thermal band excluded) image and then select only the first three bands after the transformation. Since most information is contained in the first few bands of pca-transformed image, it implies that better result can be achieved. This is confirmed as shown in table 3. The accuracy improvement is significant in the class of debris but this can be misleading and inconclusive due to small number of test points. The improvement in reef and sand class is obvious but neither significant nor impressive once the extra computational cost of pca is factored in.

6. Conclusion

Further research is still needed, however. The reef around Kai' s island is relatively large comparing to the others in the Gulf. Smaller reefs less than 100 m wide would undoubtedly be more difficult to detect since it would be represented by only a few pixels on 30-m resolution Landsat 7 imageries and most of them are likely to be mixed pixels. This is one of the topics for further investigation. More field survey data from other islands in the national park is being gathered for further study to determine the full potential and limitation of this technique

Another area of investigation is to assess the possibility of using satellite imagery to determine coral types and their healthiness. As discussed earlier, this is extremely difficult and for this study area it cannot be done on Landsat 7 imagery. It is likely that the research have to opt for higher resolution imagery from other sensors such as SPOT 5 or Ikonos.

Despite the limitations, the experiment clearly demonstrates the merit of simple classification on Landsat 7 imagery as a technique for small shallow-water coral reef detection. The achieved accuracy is high. The technique can be applied on a routine basis, something like a reconnaissance and if anything strange are detected a closer look using either high resolution imageries or field survey can be called for.

Acknowledgement

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