The Image Interpretation Module Development for an Urban Area

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Abstract: Five new satellite image interpretation modules are developed. The modules are for: 1) construction of a realistic color image, 2) feature recognition by intensity filtering, 3) removal of spurious spots by next-neighbor count comparison, 4) deviation-amplification filtering, and 5) feature recognition by spectral distribution pattern. The modules were applied to a set of IKONOS images of 8 x 8 km area of the city of Daejeon, Korea, to recognize the distribution of various features such as water resources, playgrounds, forests, etc.
Keywords: module development, urban features, water resources.

1. Introduction

In the spring semester of 2003, a lecture-laboratory class on satellite remote sensing was conducted in the Department of Aerospace Engineering of Korea Advanced Institute of Science and Technology (KAIST). By the courtesy of the e-HD.com company, the class was loaned, without charge, a complete set of satellite images of the city of Daejeon, Korea, where KAIST is located. The set was obtained by the IKONOS-2 satellite on November 19, 2001, and consisted of a panchromatic image of 1m by 1m resolution, and four-band spectral images of 4m by 4m resolution in the blue (0.45-0.52μ), green (0.52-0.60μ), red (0.63-0.69μ), and near-IR (0.76-0.90μ) wavelength ranges. These images covered an area of 8.004 by 8.004 km, and had been geometrically corrected using the standard procedure. The panchromatic image is represented by 8004 by 8004 pixels, while the spectral images are by 2001 by 2001 pixels. On each pixel, the intensity of radiation is represented by an 11-bit (2048) digital count. Interpretation of these images was the task for the class.

Initially, both the class and the image provider wished to use these images for the purpose of determining the suitability of Daejeon as the new capital of Republic of Korea. However, it became immediately clear that this purpose could not be fulfilled, because the images cover an area too small for that purpose. Therefore, the class opted to use these images to develop a means of interpreting the images by programming from scratch. This paper summarizes the results of that effort.

Various image interpretation software already exist both in the public and commercial areas. However, use of such on-the-shelf software restricts the future possibilities for extension and modification. The present work demonstrates that the needed software can indeed be developed independently.

2. Color Map Construction

The first task was to construct a realistic color map from the spectral data. A computer software named MATLAB exists that can produce a color map using the types of data contained in the IKONOS files. The software accepts a three-band (red, green, and blue) data as a three-dimensional data set, and synthesizes a color to be produced in any image-processing software. However, when a color image of the raw files was first produced by MATLAB, the produced image was black. The MATLAB software requires adjustment of intensity and contrast of the three bands in order for the produced colors to be realistic, by adjusting parameters named 'imadjust' and 'stretchlim'. Because the true colors of each features in the images are known independently, it was possible o adjust these parameters so as to create a map of realistic color. Fig. 1 shows the color image so produced.

In Fig. 1, there is in reality a mountain region in the middle. Because the IKONOS data was obtained in November, the mountain area does not show green color. One finds the urban regions in the right side and the rice field in the left side of the image.

Fig. 1. Color map of Daejeon produced.

3. Digital Number Filtering

In order to extract information on the distribution of a target feature, e.g. water surface, we developed a filtering technique based on the magnitude of the count on one chosen spectral file. In the chosen spectral file, we filtered in only those pixels with counts falling within a certain preset limits, and filtered out the rest. The intensity limits were selected so that only the desired features, such as water surface, would be filtered in. The color was chosen to maximize the discrimination by this method. For example, water surface appears dark in the near-IR image. By filtering in only the low counts I this file, water surface can be discriminated. Figs. 2 and 3 show typical results.

Fig. 2 is produced by filtering in the counts within the range of 83 to 222 in the near-IR file. In the figure, the dark region is the water surface. The river, named ' Gapcheon" is seen prominently.

In Fig. 3, the distribution of the playgrounds is shown. Playgrounds are seen as black dots in this figure. This figure was obtained by filtering in the counts in the range of 482 to 596 in the green file. The region covered in Fig. 3 is a new town called "Doonsan." This town has many apartments and therefore a relatively high population density. Consequently, there are several schools which have a playground nearby.

4. Spurious Spot Removal

In Fig.2 (b), we see many spurious dark spots which are too small to be a water surface. By comparing with the panchromatic image, it was concluded that these are the shadows of buildings and trees. Unfortunately, water surface and shadows have similar digital counts in the near-IR image.

In order to acquire information only on water surface, these spurious spots are removed by applying a second filter. In this filter, an otherwise acceptable pixel count is rejected if the pixels around it have counts different from that at the center. The sizes of these spots, represented by the pixel number N, are varied. Figs. 4(a) to (c) show the results. These figures are shown as negatives. As a result, black and white are reversed in these figures.

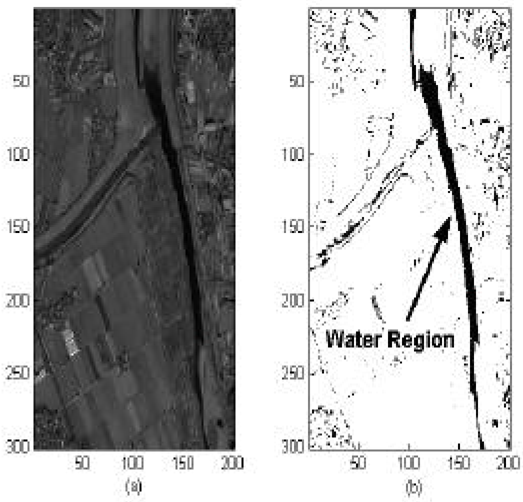


Fig. 2. (a) Near- IR image (b) Filtered image.

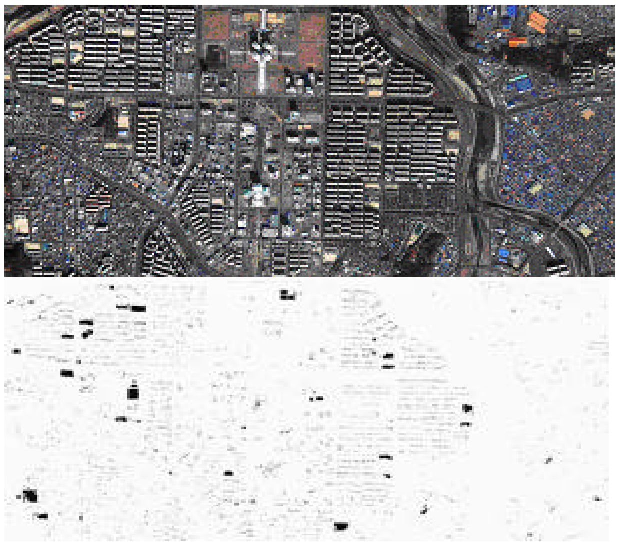


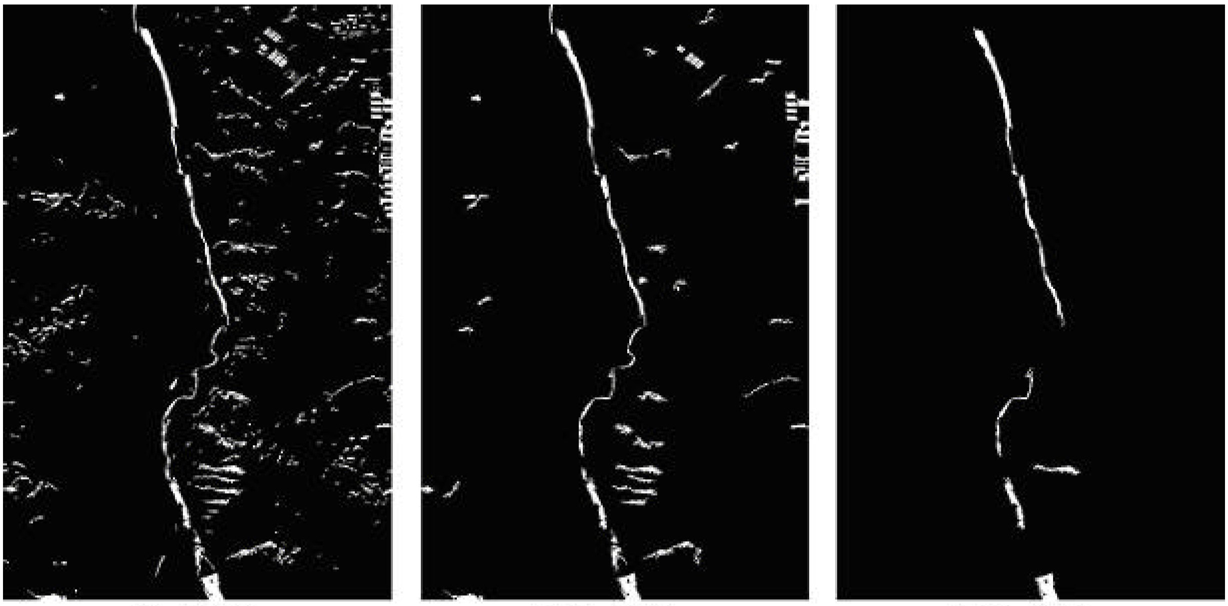
Fig. 3. Filtered image showing playground distribution

In Fig. 4(a), N is 10. Comparing with Fig. 2(b), one sees that the very small spots are removed, but medium sized and large spots still remain. In Fig. 4(b), N is 100. Here, the medium-sized spots are now gone. In Fig. 4(c), in which N = 500, even the large spots are gone, leaving only the main water surface, "Gapcheon", to be seen.

5. Deviation-Amplification Filtering

If one is to identify a very specific target feature, e.g. a mineral deposit, an even sharper discrimination than that in Section 3 above is needed. For this, we developed a filtering method in which the deviation from a specified template is amplified. We first determine the spectral characteristics, represented by the counts in each of the spectral bands, of the target feature. Then a template, consisting of N by N pixels with those spectral counts, is created. This template is laid over the image and swept. The difference in the counts between the image and the template is calculated for each pixel, and amplified by raising it by a fourth power. This value is summed over all the pixels on the template. The area under the template which gives this amplified deviation below 10^{5} in the normalized count is then admitted. This method somewhat resembles the ' wavelet technique' in signal processing in that only a segment of the total information is processed at one time and summed over the entire domain of information.

In Fig. 5(a), a template of arbitrarily chosen counts is created. A distinct pattern emerges by filtering by this template as seen in Fig. 5(b). Because the dark images in Fig. 5(b) do not represent the water surface, it is believed to represent a farm crop.



N = 10 N = 100 N = 500

Fig. 4. Removal of spots using the spot-removing module.

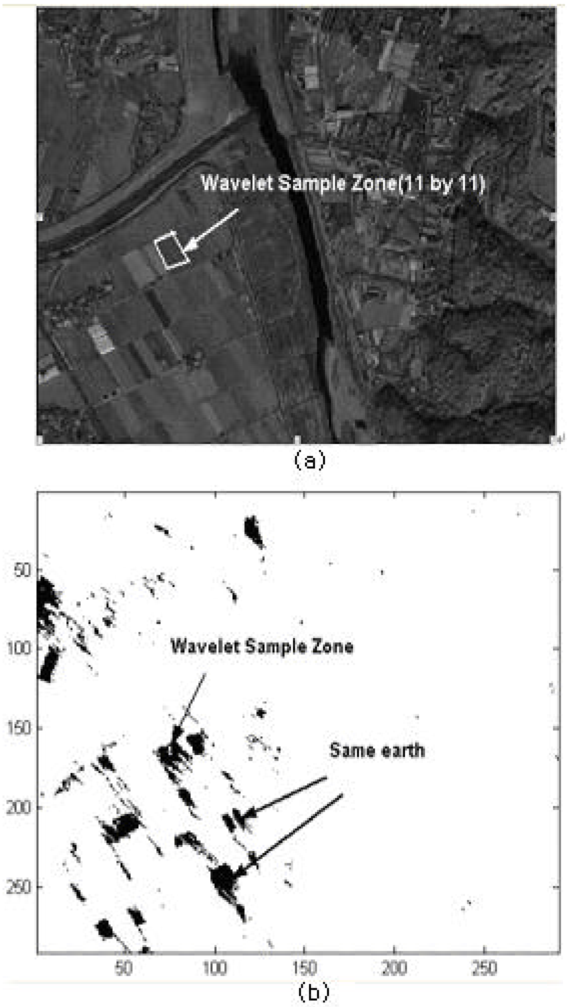


Fig. 5. (a) The template of 11x11 pixels. (b) Result of the deviation-amplification discrimination filtering.

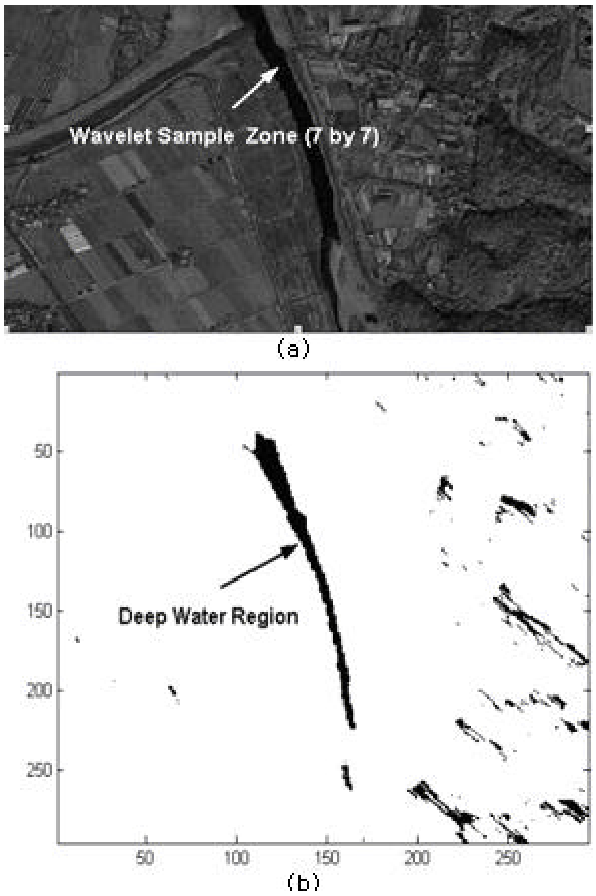


Fig. 6. Water surface identified by deviation-amplification method.

In Fig. 6, the technique is applied to the water surface. This image is different from Fig. 2 (b) and Figs. 4(a) to (c). The true merit of this technique is yet to be explored fully.

6. Determination of Categorized Areas

In this endeavor, we categorize the area into four categories: sand area for which the counts in the near-IR values are much larger than those of the three other bands; the water area for which the blue and green band counts are larger than the red and near-IR counts; the forest area for which the green and red band counts are much smaller than the near-IR counts; and the urban area for which all bands have large counts. The areas in these four categories are then calculated by integration. Figs. 7 and 8 show the results.

By comparing Fig. 7(a) with 7(b), one understands that many apartment blocks are correctly categorized in the urban area. The river is correctly categorized in the water category. As mentioned, because the image is obtained in November, the mountain areas are devoid of green and therefore are categorized into the sand area. The summation of all areas slightly exceeds 100% because some regions overlap.

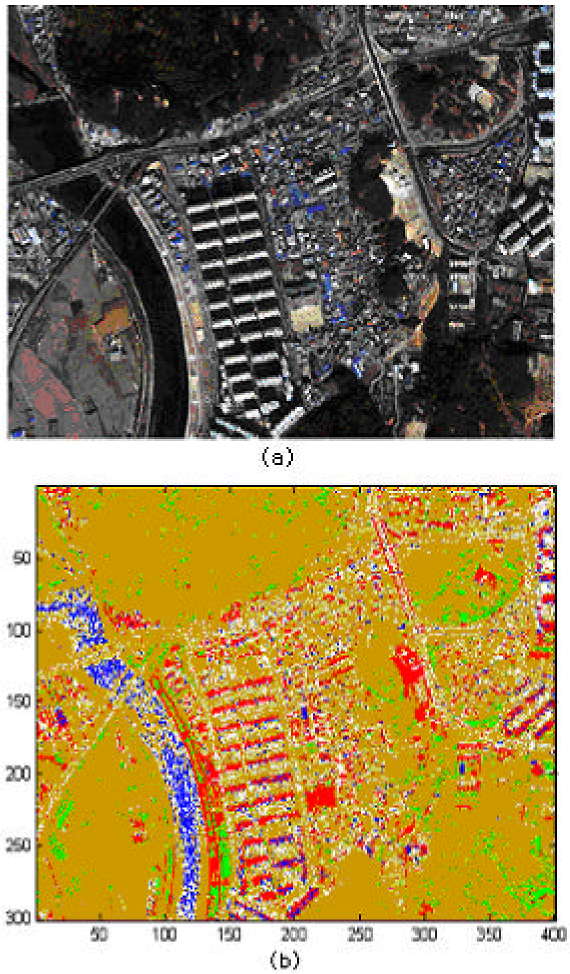


Fig. 7. Areal categorization of south-west Daejeon: sand (yellow earth), water (blue), forest (green), and urban (red). Total area = 1931216 m^2, sand area = 1601856 m^2 (83.0%), water area = 62560 m^2 (3.2%), forest area = 62464 m^2 (3.2%) and urban area = 170304 m^2 (8.8%).

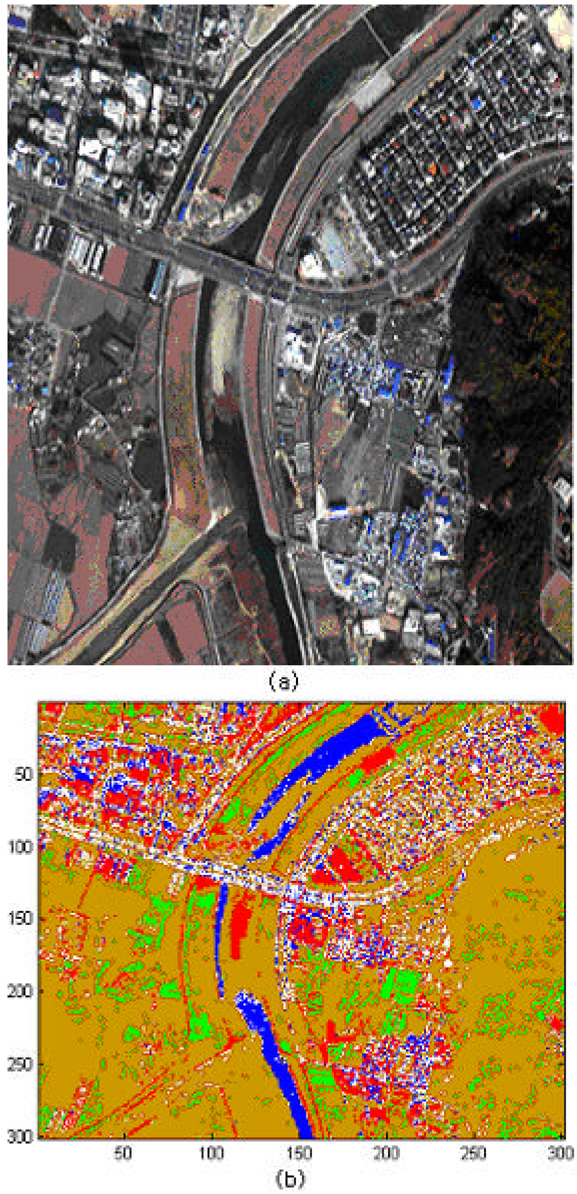


Fig. 8. Areal categorization of north-west Daejeon: Total area = 1449616 m^2, sand area = 1156704 m^2 (79.8%), water area = 121744 m^2 (8.4%), forest area = 78352 m^2 (5.4%), and urban area = 161520 m^2 (11.1%).

Figs. 8(a) and (b) show the result for another region. The region is more complex than that analyzed in Fig. 7. Detailed examination shows that the areal categorization is correct.

7. Conclusions

We developed five interpretation modules independently. These modules are applied to a 8 km x 8 km area over Daejeon, Korea, to discriminate water areas, playground areas, forest areas, and urban areas. Using one of the developed modules, spurious spots due to unwanted shadows are eliminated. A sharp discrimination is made possible by using another of the developed modules based on the principle of deviation amplification.

8. Acknowledgement

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References

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