Multilook scene classification with spectral imagery

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ABSTRACT

Scene classification using multiple views for an urban/rural scene was studied. Visible/Near Infrared (VNIR) imagery was acquired over Fresno, Ca, on July 13, 2003 using the 4-color Quickbird multi-spectral imager. Four scenes were acquired at view angles of +60, nadir, -45, and –60 degrees on a descending pass. Bi-directional reflectance function (BDRF) effects were present. Analysis was conducted at 10-meter spatial resolution. Variations in reflectance with view angle aided in the extraction of surface characteristics, and allowed for improved classification accuracy.

1. INTRODUCTION

Traditional optical remote sensing systems have consistently produced nadir views of the earth. This was particularly true for the Landsat series of satellites. More recently, sensors which provide non-nadir views have emerged. The MISR sensor on the NASA Terra platform was designed to provide 4 spectral bands at multiple angles: 0, 26.1, 45.6, 60.0, and 70.5 degrees[1,2,3]. The multiple views allow for studies of surface roughness and atmospheric (aerosol) effects at the moderately coarse spatial resolution offered by MISR (275 and 1100 meters). Observations from that sensor motivated consideration of how the signficant off-nadir pointing capabilities of modern commercial remote sensing systems could be exploited. Previous work from airborne systems indicates that Bi-Directional Reflectance Function (BDRF) effects are useful for distinguishing surface characteristics at higher spatial resolution, and it seemed that doing so from a space platform would be useful [4,5,6,7].

2. OBSERVATIONS

A data collection was arranged using the Quickbird satellite, operated by Digital Globe [®.] Launched on October 18, 2001, the satellite operates at an altitude of 450 km. The relatively low altitude allows a spatial resolution of approximately 0.66 m for the panchromatic sensor (PAN), and 2.67 m for the 4-color multispectral imager (MSI). The data collect was conducted on July 13, 2003, from 1836-1841 UT. Four images were acquired. Each image is taken over a 4-second interval. Figure 1 illustrates the orbit during data acquisition, and Table 1 gives some of the pertinent values. The target area, Fresno, California, is at a nominal location of 120W, 37N. Local time is approximately 1040. Given the relatively low solar elevation, the orbit track differs significantly from the ideal, which would be to fly along a path that intercepts the solar vector. .

Table 1.

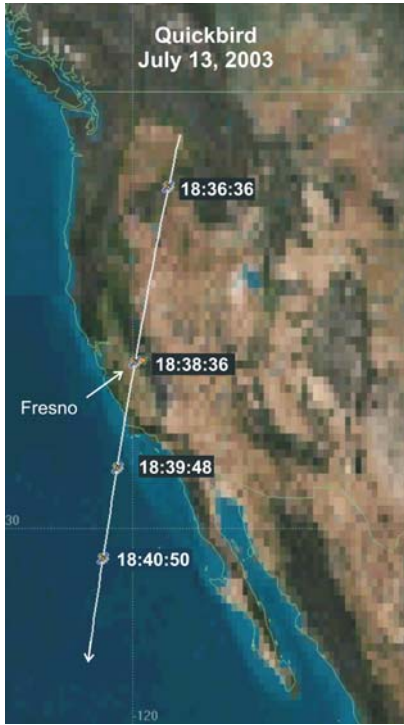| Image #	1	2	3	4
Acquisition Time (start, UT)	18:36:36	18:38:36	18:39:48	18:40:50
In Track View Angle	59.6°	-0.8°	-47.2°	-61.0°
Cross Track View Angle	2.3°	-3.4°	-6.0°	-8.0°
Off Nadir View Angle	59.6°	-3.5°	47.4°	61.2°

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Figure 1. Quickbird orbit track for the data collect.

Figure 2. Quickbird data, nadir view, false-color IR image (bands 4,3,2) for the target area.

Figure 3. Near-infrared images from 3 angles – images 1, 3, 4 as R, G, B, respectively.

Fresno was chosen as a study area for reasons primarily associated with the high cost of the data collect. We required a target area that had a high probability of clear weather. This precluded coastal California, an area we normally prefer for proximity. A relatively flat area was desired to preclude image registration problems. We wanted a reasonably rural target area, with flat grass areas (parks), agricultural areas (orchards, fields), and some urban character, including an airport (flat concrete surfaces). The north-west portion of Fresno met these criteria. Ground-truth efforts were conducted by a colleague conveniently living in the area.

The data were delivered as geotiff files. The data had all been resampled to 0.66/2.66-m spatial gridding. Keeping in mind the dramatically larger field of view the off-nadir scenes encompassed, this then had a peculiar consequence in that although the nadir scene was only 3.3 GB (pan), the ±60° views were some 43 GB in size (each) for the complete panchromatic scenes. This took some effort to deal with, even for the relatively small volume required by the MSI data.

3. ANALYSIS

For the analysis process, the nadir view was orthorectified, based on the SRTM 30-meter digital elevation model[8]. The process was conducted in ENVI. The other 3 scenes were then warped to the nadir view. There were a variety of problems with this approach, which was partly motivated by a fairly significant pointing error in the off-nadir views. The problems are primarily associated with the failure of the process in the more varied terrain north-east of Fresno. The second-order polynomial warp was unable to compensate for the terrain. Future work will include a more robust approach to this segment of the analysis, most likely by conducting an ortho-rectification of the off-nadir views prior to merging the data sets. A secondary problem had to do with perspective effects on tall features such as trees and buildings. The relative shift of these features with respect to the ground caused artifacts that manifested as mixed pixels. For now, classification errors have been mitigated by resampling the combined data set to 10-m spatial resolution (4x resampling). This has the useful side effect of reducing the data volume to be handled during our initial

studies. Figure 3 gives an overview of the near-infrared data from the 3 off-nadir images. The coloration is not strong, but the variation in color reflects the variation in reflectance characteristics of the scene. The urban area is fairly strongly affected by registration errors around buildings and roads. The airport area is boxed in white; the analysis below will focus on this area.

For the initial analysis, we will focus our attention on the nadir MSI data, and the near-IR data from the non-nadir views. The reasoning is two-fold. First, aerosol effects are of increasing importance for shorter wavelengths, and we want to avoid those effects as a topic for now. A related aerosol study will be conducted using the multiple views by a colleague. The second reason is that we are interested in the added value of the multiple views, and a focus on the four near-IR bands provides a convenient handle for such considerations.

In order to remove remaining instrument gain and atmospheric effects, all 4 bands were scaled to common histogram end-points. Table 2 shows the data value ranges. Figure 4 shows the histogram of data values found after the scaling was done. This is effectively a flat-field normalization, as would be used to convert to reflectance. The histograms are equal in value at DN = 0, and DN =2000.

Some sample spectra are illustrated in Figure 5. The angular effects are fairly modest, but the small set of regions chosen for illustration show that the reflectance curves vary from the convex to the concave. Note that image 2 is the nadir scene, image one is from the north, and would have the largest forward-scattering character.

The question of interest, here, is what is the nature of the information provided by the additional images, and what does this contribute to the understanding of the scene. Specifically, is the scene classification process improved by the addition of the multiple images? To address this question, several classification procedures were followed. They showed some improvement in the classification process, but produced a conclusion which was somewhat marred by the training process, and the additional knowledge provided by the additional scenes – that is, the training process was modified by the addition of the new images. In order to remove this bias, a simple isodata classifier was run.

Figures 6, 7, and 8 show the small scene around the airport in a false-color IR image, the results from analysis of the 4 nadir view bands, and the results from those 4 bands plus the off-nadir near-IR data. Statistically, the results from the 7 bands were an improvement, based on confusion matrices and a number of "ground-truth" regions of interest defined by inspection. Matching between the observed classes and those inferred by the isodata classifier was fairly straightforward, but probably introduces some human bias. Given that caveat, the results for 4 bands were 62% accuracy, while 7 bands gave 74% accuracy.

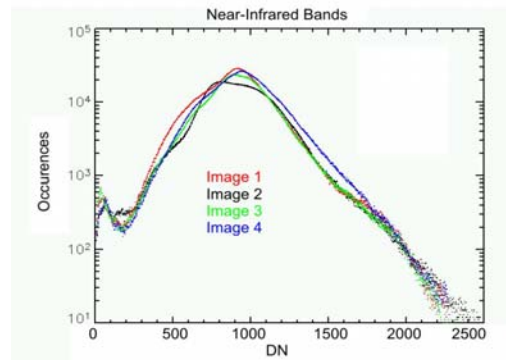| Table 2		
Image	Minimum DN	Maximum DN
1	112.0	1036.00
2	60.0	1206.00
3	71.0	1158.00
4	125.0	1052.00

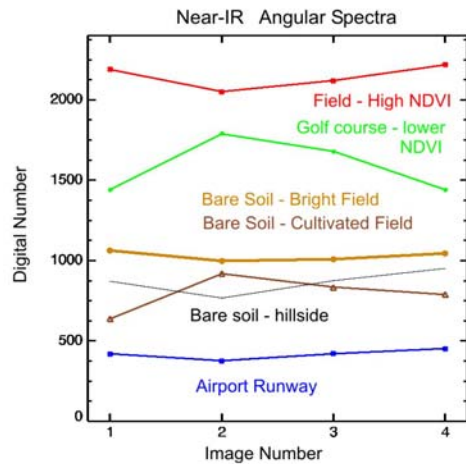Figure 4. DN distribution for histogram normalized NIR bands

Figure 5. Angular variations of near-infrared radiance as a function of view-angle.

A more intuitive understanding of the differences may be obtained by noting that the 4 band classification results mis-identified a large water pond as dark soil. The addition of angular variation as a discriminator corrects that error.

Figure 6. Nadir view data- bands 4, 3, 2 for R, G, B respectively. Note the bright red region in the lower right corner – the one field still in production. Other darker red regions on the right side are fields that have been harvested, or orchards.
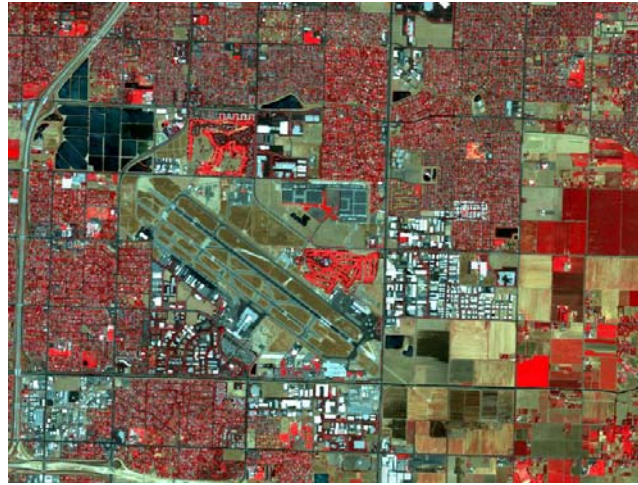

Figure 7. Iso-data classifier result for the 4 nadir view MSI bands. Classifier was run for 5-10 classes, up to 20 iterations, with 100 pixels required per group. Change threshold of 5%, maximum class standard deviations of 1.0, minimum class distance 5.0, per ENVI default values.

Harvested fields
Vegetatation
Urban
Urban 2
Concrete
Concrete or Light Soil
Light Soil
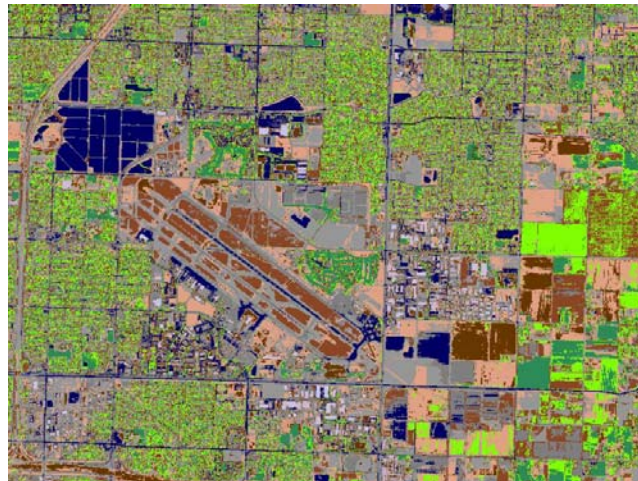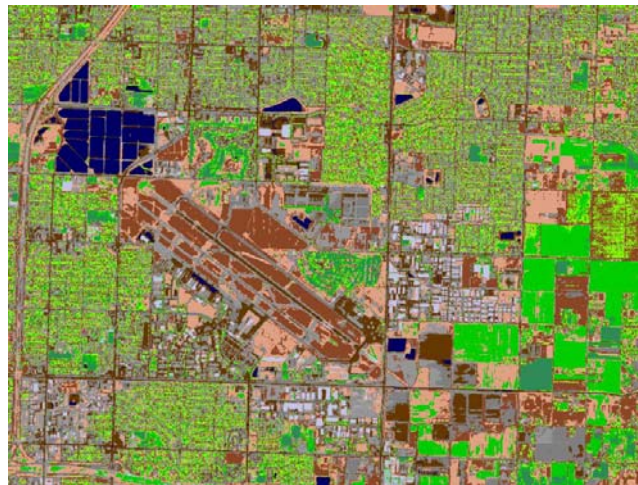Soil Near Runway
Dark Soil
Ponds

Figure 8. Iso-data classifier result for 4 nadir view bands, plus 3 off-nadir Near-IR bands. By contrast with the 4-band result, there was a relatively poorer discrimination between concrete and very light soil.

Note that "dark soil" is cultivated soil which has recently been irrigated, a step that usually occurs shortly after harvest, as the soil is prepared for the next crop.

Harvested Fields
Light soil - some vegetati
Vegetation

Urban
Concrete
Concrete, Bare Soil
Light Soil
Soil Near Runway
Dark Soil
Ponds

4. CONCLUSIONS

We believe this is the first time that high-spatial resolution multi-spectral imagery has been acquired from space at multiple (more than 2) view angles. The exercise gives us a data set where BDRF effects can be studied in an urban/rural area. Initial analysis shows promising results, including a 12% in classification accuracy. Several problems arose during the analysis, mostly associated with registration, and the variation in spatial resolution with view angle. Future work will involve more robust image registration processes. We will study the utility of the panchromatic imagery for the role of BDRF. A fundamental question will be the effect of restricting wavelength range in the consideration of BDRF effects [7]

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