Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.

PRACTICAL ASPECTS OF IKONOS IMAGERY FOR MAPPING

Mahendra Kumar, Technical Applications Manager, Intergraph Philippines, mkumar@intergraph.com
Ofelia T Castro, Chief, Photogrammetry Division, NAMRIA, The Philippines, photo@namria.gov.ph

KEY WORDS: IKONOS, Philippines, Accuracy, Mapping, Landcover

ABSTRACT

Availability of high-resolution imagery, such as IKONOS (from Space Imaging Corp), has opened new possibilities for satellite-based mapping. This paper aims to share the practical experience of authors in using IKONOS imagery for mapping application in a production environment. Authors are involved in an IKONOS based land-cover mapping project jointly undertaken by Intergraph Philippines Corporation and the National Mapping and Resource Information Authority (NAMRIA), of the Philippines**.** As IKONOS imagery applications are still in its immerging phase, it is felt that the experiences shared herewith will benefit those considering the use of IKONOS imagery as one of the data sources for mapping applications. This paper aims to present some of the features that differentiate IKONOS imagery for mapping applications from other commercially available satellite imagery.

PROJECT AREA

The project covers an area of approximately 1,400 square kilometres in Sorsogon province in South Luzon, Philippines. The prevalent land-cover features are diverse, such as, coastal areas, mangroves, agriculture area, townships, plantation and dense forest. The whole project area was imaged with 1-meter resolution panchromatic IKONOS imagery. Three sub-areas within the project area were also imaged with 4-meter multi-spectral IKONOS imagery. The areas imaged with the multi-spectral images primarily include mangroves and townships. The project uses IKONOS Carterra^{TM} Geo imageries and a set of recently surveyed ground control points. The images are geo-referenced and mosaiced to provide a backdrop for interactive land-cover mapping.

The map on the right shows the location of the project area within the Philippines. The above map shows the entire project area in green as imaged with IKONOS panchromatic data. The areas marked with in red were imaged with 4-meter multi-spectral imagery.

Fig. 1

OVERVIEW OF IKONOS DATA

IKONOS images are acquired as 1-meter resolution panchromatic and 4-meter resolution multi-spectral images. While the panchromatic images represent the visible range of the spectrum, the four bands of multi-spectral images represent the red, green, blue and near infra-red range of the spectrum. A pan-sharpened color imagery can be generated by merging 1-meter resolution panchromatic image with the 4-meter resolution multi-spectral bands to generate true-color or a false-color images at 1-meter resolution. These 1-meter resolution color images provide exceptional depth in color and clarity of detailed for feature extraction.

Table 1 provides the spectral ranges associated with the IKONOS images.

Space Imaging offers various imagery products derived from these two types of IKONOS image data. Image resolution and level of processing performed to derive certain accuracies characterize these products. Government agencies can also request for IKONOS stereo pairs, acceptance of which is subject to approval from the US government. Recently Space Imaging has also announced the availability of the much-awaited Geo Ortho Kit product that includes an Image Geometry Model (IGM) for photogrammetric processing. This would enable users to generate precise ortho-images using an existing terrain model and GCPs. As users have a wide variety of parameters to consider in order to appropriately define the imagery product best suited for their needs, the product details and the various options available will not be discussed here. Interested users may visit the Space Imaging web site at www.spaceimaging.com for more detailed information.

Data Type	Spectral Range
Panchromatic	0.45 to 0.90 microns
Multi-spectral Band1	445 – 516 nm (Blue)
Multi-spectral Band2	506 – 595 nm (Green)
Multi-spectral Band3	632 – 698 nm (Red)
Multi-spectral Band4	757 – 853 nm (NIR)

Table 1

11 BIT V/S 8 BIT: THE ADDITIONAL INFORMATION

The additional data bits were particularly useful for enhancing features under dense cloud and other shadows. It was observed that the useful range of the histogram was from approximately 80 to 800. In other words most of the information was within the first 10 bits out of the 11 bits available per pixel. As seen in the Fig. 2, the right side of the histogram extends very lean and most of the data is represented towards the left. Although the image is 11 bit, the computer display systems at present can only display 8 bits per color. This means that although the user has the flexibility to interactively use any range from the available 2048 bins for interoperation and analysis, computer display and the hardcopy out-put can only best represent a sub-sample (8 bits per color) of the 11 bit radiometry.

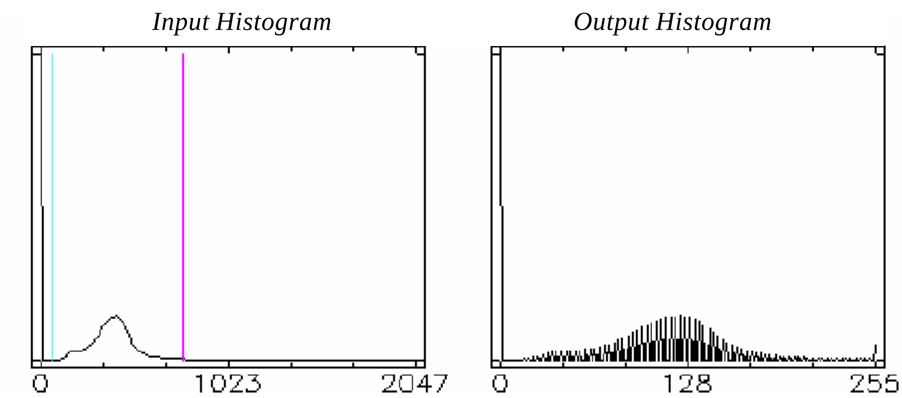


Fig. 2

At the same time the additional bits make the data size larger compared to the traditional 8-bit data. For example Space Imaging uses two bytes per pixel to store the 11 bit data. Thus, at 1-meter resolution, a one square kilometre area color image (three bands RGB) will have 3 MB storage size for 8-bit data. At the same time the 11-bit image for the same area would need 6 MB of storage. This therefore will call for higher hardware requirements and software processing capabilities as commonly used systems and procedures use 8-bits of image data per band. Further, for larger areas, creation of seamless mosaics can push the processing systems to their limits and users will have to either use virtual mosaics or generate image tiles accessed through meta-data definitions. Similarly plotting of such large data at large scales (say 1:5,000) would need sufficient allocation of system resources and efficient provision of plot file handling and data transfer from computer to plotter.

LAND COVER MAPPING

In order to achieve best results, the land cover mapping was performed interactively using the panchromatic image as a backdrop. This way the features could be best identified and generalized as per the requirement of the project. As an example, polygons were created for the roads that were wider then two lanes wide, whereas the trails and narrow streets were generalized with the adjacent prevalent features. Similarly, the group of houses were digitised as built-up areas, while the small isolated ones were ignored.

As represented in the Fig. 1, for selected areas the multi-spectral images were acquired. These multi-spectral images were used to generate pan-sharpened true color and false color imageries.

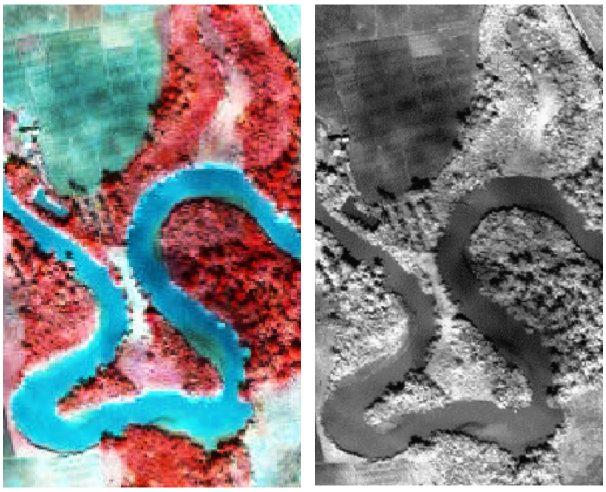


Fig. 3

These sharpened imageries provided an information-rich backdrop for identification of feature classes. Although it is well understood that the pan-sharpened images offer more information compared to the pan data alone, the productivity gain and accuracy achieved were clearly observed. Images in Fig. 2 represent the samples of panchromatic and color image options. It was observed that for a production environment, the color images required lesser supervision, provided more operator ease, reduced instances of misinterpretation and provided for higher speeds in interactive interpretation-cum-delineation. Therefore it is felt that the present price difference between pan and sharpened imagery will be more then compensated by the gains through above benefits for this kind of application.

Quality of the final image product depends on the input data. As the IKONOS satellite uses various passes (Fig. 5) to cover the entire area, various parameters affect the visual quality of the individual component images. In addition to the various environmental changes and land cover changes that would affect the image quality, it is interesting to note how the image collection geometry can also affect the appearance of the image because of the specular reflections. Fig. 4 represents a part of the image no. 62272(2 of 2) as shown in Fig. 5. This image shows that water has come close to saturation instead of being represented towards the lower end of the histogram while mangroves are represented in low contrast.

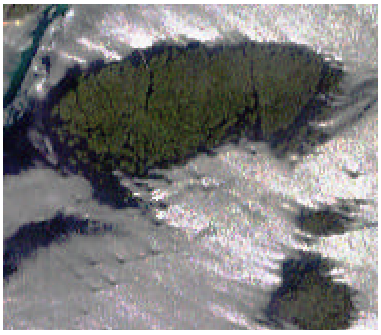


Fig. 4

Although images as these can provide useful information for certain applications, these bright target returns are generally undesirable. As IKONOS images can be acquired at varying collection geometry, the visual quality of adjacent images could be quiet different and a uniformly toned mosaic might not be practically possible. With IKONOS, users can specify azimuth constraints, but it may cause collection delays. Imagine mosaicing this image with the adjacent image where water would normally appear close to black.

GROUND CONTROL POINT (GCP) REQUIREMENT

The control point requirements for IKONOS images can be different compared to those for other satellite data. The main reasons for this are the varying angle in which the images could be captured by satellite, overlap between the images, and shape and size of the individual images that could be provide by Space Imaging. Fig. 5 shows the image index for the project area as mapped with IKONOS images.

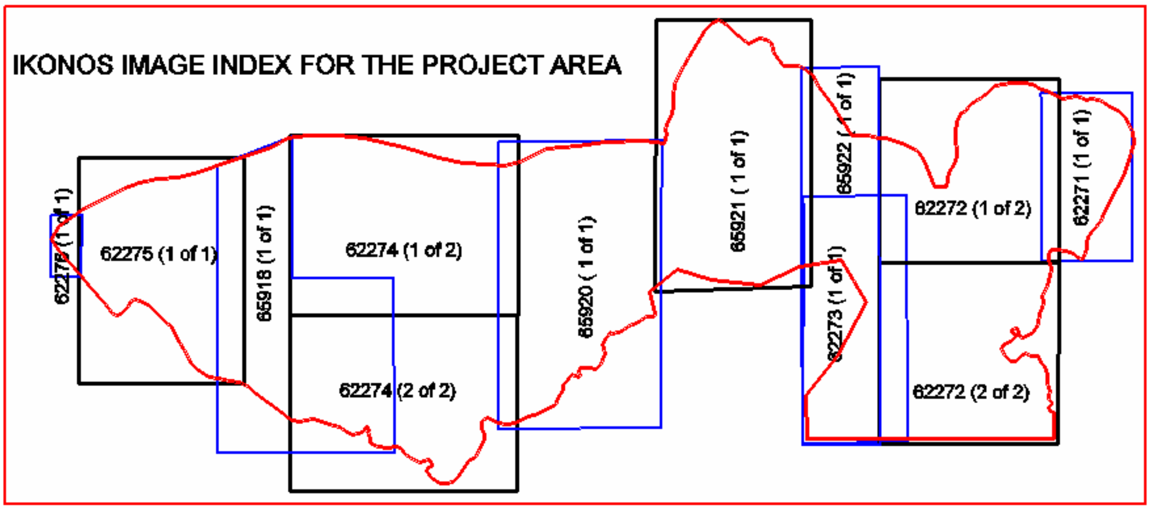


Fig. 5

As the images can have different collection geometry, mosaicing these images without rectification using the narrow image overlap would lead to unmanageable error propagation. Therefore all the images need to be separately geo-referenced. For a large area like this, it would not be possible to determine the shape, size and collection geometry of the individual images that could be delivered by Space Imaging under a standard imagery order. This leads to uncertainty on the part of control point requirement as the actual requirement in terms of their number and location can only be determined once all the images have been received. For the large and remote areas, such as this, the cost of control point survey could substantially increase the overall project cost. Therefore, the project manager has to deal with this uncertainty in cost and duration.

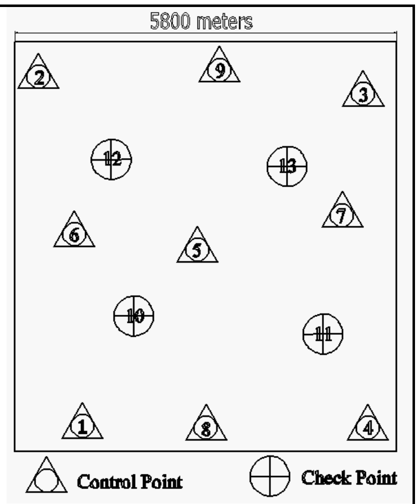
As the project area did not have sufficient usable control points, a configuration of 5 control points as presented in Table 3 and Fig. 6 was identified for each image. In order to avoid any possible misinterpretation of desired control locations, the field survey team was provided with image-maps of the control point locations at 1:3,000 scale and approximate coordinates of the control points. The control points were GPS-surveyed with sub-meter accuracy. Each image was thus geo-referenced with five GCPs well distributed over the image.

ACCURACY ACHIEVED WITH GEO PRODUCT

In order to achieve a good understanding of the accuracy achievable with the imagery, the geo-referencing of the image was performed in two settings. For this purpose an image of a relatively plane area in Metro Manila was used. Features from existing vector data at 1:5,000 scale were used as control points. The map features provided enough control points with sub-meter accuracy for geo-referencing of the image. Fig. 6 shows configuration of points used.

Number of Control Points: 9		Standard Error: 1.5014 meter		
Number of Check Points: 4		Model: Projective		
Point ID	**Point Type**	**Residual X**	**Residual Y**	**SSE**
1	Control	0.3806	1.0124	1.0816
2	Control	0.5838	0.8086	0.9974
3	Control	0.5890	1.8662	1.9569
4	Control	0.7862	0.9250	1.2140
5	Control	-0.3049	-0.7350	0.7957
6	Check	-1.4754	0.3341	1.5128
7	*Check*	*-2.0918*	*-0.8672*	*2.2644*
8	Check	0.4482	-1.5053	1.5706
9	Check	1.0842	-1.8389	2.1347
10	Check	0.8859	0.1173	0.8937
11	Check	0.1811	-1.2701	1.2830
12/14	Check	-1.1311	-0.5154	1.2430
13/15	Check	0.2585	0.9385	0.9735

Table 2. Geo-referencing results with 9 control points



Distribution of Points

Fig. 6

Number of Control Points: 5		Standard Error: 1.1767 meter		
Number of Check Points: 8		Model: Projective		
Point ID	**Point Type**	**Residual X**	**Residual Y**	**SSE**
1	Control	-0.2472	0.2138	0.3268
2	Control	0.4463	0.4636	0.6435
3	Control	-0.2298	0.1877	0.2967
4	Control	0.4716	0.3949	0.6151
5	Control	-0.4409	-1.2600	1.3349
6	Check	1.8094	-0.0425	1.8099
7	Check	2.6208	1.7919	3.1749
8	Check	-0.2633	2.1975	2.2132
9	*Check*	*-0.9538*	*3.0410*	*3.1870*
10	Check	1.1516	0.5698	1.2849
11	Check	0.4824	-0.6947	0.8457
12/14	Check	-1.0103	-0.0715	1.0128
13/15	Check	0.5880	1.9161	2.0043

Table 3. geo-referencing results with 5 control points

Image Collection Geometry:

Cross Scan: 0.92 meters
Along Scan: 0.90 meters
Scan Direction: 0 degrees

Nominal Collection Azimuth:
129.7638 degrees

Nominal Collection Elevation:
67.81695 degrees

These results show that the IKONOS products can be easily used for large scale mapping workflow for a relatively flat area where a sufficient number of control points can be provided. Further, if the final product is an image-map, as a compromise, the visual quality of such maps may compensate for certain degree of ground accuracy. As the IKONOS products are not corrected for the relief displacement, the accuracy will degrade with increased undulations of the terrain.

CONCLUSION

IKONOS images have certainly opened new possibilities for satellite-based mapping. New applications are continuously emerging. IKONOS images and the associated product delivery are somewhat different from the other commercially available satellite data products in many ways, which makes the processing, and applications different as well. Based on above discussion, following aspects should be considered while embarking on IKONOS data application for mapping:

- IKONOS data does not follow the traditional scene-based image delivery. The images are provided and priced based on the actual area that would be imaged. Users are thus required to exactly demarcate the project area on a map for ordering the data. If the project area is in the form of a simple shape, the corner coordinates can also be provided. Various data products offered by Space Imaging can serve different applications and thus users have a better choice then ever before.
- The 11-bit data offers more radiometric depth and thus is particularly very helpful in resolving features under dark shadows. At the same time, the increased file size poses data processing and handling challenges.
- For mapping applications, a pan-sharpened image proved to be of higher value and flexibility when compared to the slight cost difference of panchromatic images. Along with the various environmental factors, the image collection geometry may severely affect the visual quality of the image, which could make it difficult to create a tone-balanced mosaic.
- The exact location and number of GCPs required can only be determined after the images have been acquired by the satellite. This puts a challenge in project planning and cost estimation for mapping new areas.
- As the Space Imaging Carterra™ Geo product is not corrected for terrain distortions, the geo-referencing accuracy for the Carterra™ Geo product is largly dependent on the terrain undulation. The analysis provided here concludes that Carterra™ Geo images can be used for mapping at 1:10,000 scale provided the terrain is relatively flat and sufficient number of control points are available. For applications, where small amount of accuracy can be traded for the unmatched wealth of visual information, image-maps generated at 1:5,000 scale can prove to be a versatile and fast method of acquiring large scale visual maps.

REFERENCES

Space Imaging Corporation; www.spaceimaging.com

Image Courtesy: National Mapping and Resource Information Authority (NAMRIA) for all the IKONOS images.