Updating topographic map using SPOT 5 satellite imagery

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Abstract: SPOT 5 satellite imagery (PAN &XS) with a spatial resolution up to 2.5m and a 60km x 60 km coverage, has a great capabilities for topographic mapping. This paper describe processing procedure of SPOT 5 imagery for topographic map revision which have been developed recently in the Remote Sensing Center of the Ministry of Natural Resources and Environment (RSC/MONRE). In this procedure Ground Control Points were collected using GPS measurement which allow geometric correction of large block of SPOT scenes with high accuracy. SPOT images are rectified to created orthophoto-imagemap using DEM generated from 1: 50 000 map. In order to support features identification SPOT XS and SPOT PAN have been merged together by the Brovey transformation. The interpretation process has been carried out manually in the printed image map. It is found that SPOT 5 images can be used for updating topographic map at 1: 25 000 scale or even 1: 10 000 scale depending on accuracy of geometric correction.
Keywords: Updating, SPOT 5 PAN&XS, DEM, topographic mapping, orthorectification, imagemap, interpretation

Introduction

Updating topographic map is significance for resources and environment monitoring as well as for social – economic development. This task even more important for developing countries like Vietnam.

The Remote Sensing Center of Ministry of Natural Resources and Environment (RSC/MONRE) has applied satellite imagery for topographic map revision since 1985 using various kind of data including KAFA 1000, KATE 200 (Rusian), Landsat 5 TM, Landsats 7 +ETM, SPOT 1-4. However, due to limitation of spatial resolution of these kind of data, maps to be updated are mainly ranging from small scale of 1 /1 000000 to medium scale 1/ 50 000. In 2001 the Center has tried to use SPOT PAN 10 m images to update 1: 25 000 scale topographic map in the southern parts of Vietnam where surface's features are rather simple. Although results are acceptable but a large amount of field works had to be conducted.

Recently appearances of Very High Resolution(VHR) data such as SPOT 5 PAN(2,5m), IKONOS(1m), QuickBird (0.7m) has opened up possibility for map revision at large scales such as 1/25 000, 1/10 000 or even 1/5 000.

The SPOT 5 Pan image has a number of advantages compared to other kind VHR data. These are high frequency of revisit, large coverage, cost effectives with price/1km^2 are rather low. Consequently, it has been applied extensively in Vietnam for mapping purposes. The following table describe some properties of SPOT 5 satellite and high resolution data.

Table. 1: properties of SPOT 5 satellite and data.

Instruments	HRG (High Geometric Resolution) HRS (High-Resolution Stereoscopic) Vegetation
Spatial resolution	Panchromatic: 5 m, 2.5m (HRG) Multispectral: 10m (HRG), 20m (SWIR) Vegetation: 1 km
Radiometric resolution	8 bits
Ground coverage	60 x 60 km
Orbit Altitude Inclination	Sun synchronous 822 km 98°.7 (i.e., near-polar orbit)
Revisit period	- 26 days, each SPOT satellite flies over the same points on the ground. - Off-nadir viewing by 1-4 days depending on the latitude.
Viewing angle	-26.4^o to + 26.4^o

During the period from later 2003 to 2005, the RSC/MONRE have been given a task to update 164 map sheets at 1/25 000 scale over Northern part of the country using SPOT 5 imagery.

The objectives of this paper is to introduce process of map revisions at 1/25 000 scale which have been tested and implemented successfully in the RSC, MONRE. In fact, the procedures can be applied also for 1: 10 000 scale map, but some aspects such as GCPs need to be improved to meet with technical request of this kind of map.

Project areas, data used and methodology

Project area

Project site occupies large portion of Red river delta, including 149 map sheets of 1/ 25.000 scale in the Northern region of Vietnam. Terrain surfaces are diversity from low flat area along rivers and coastal zone to hilly and mountainous areas extends in a North and West direction. Because of its large coverage, the project areas consists of almost all kind of typical topographic features including hydrographic (rivers, lakes), transportation network (roads, paths) , residential (urban, villages), vegetation (rice, crops, forest).

Data used

SPOT 5 data including pairs of SPOT PAN 2.5m and SPOT XS 10m have been delivered gradually based on possibility of scenes acquired with cloud coverage less than 10%.

Currently, the project the implemented area consisted of 24 pair scenes with various degree of overlap. Images were acquired with different viewing angle from 1° to 26.4^o as maximum.

Methodology

The mapupdating procedure in the RSC, MONRE are presented in the diagram below:

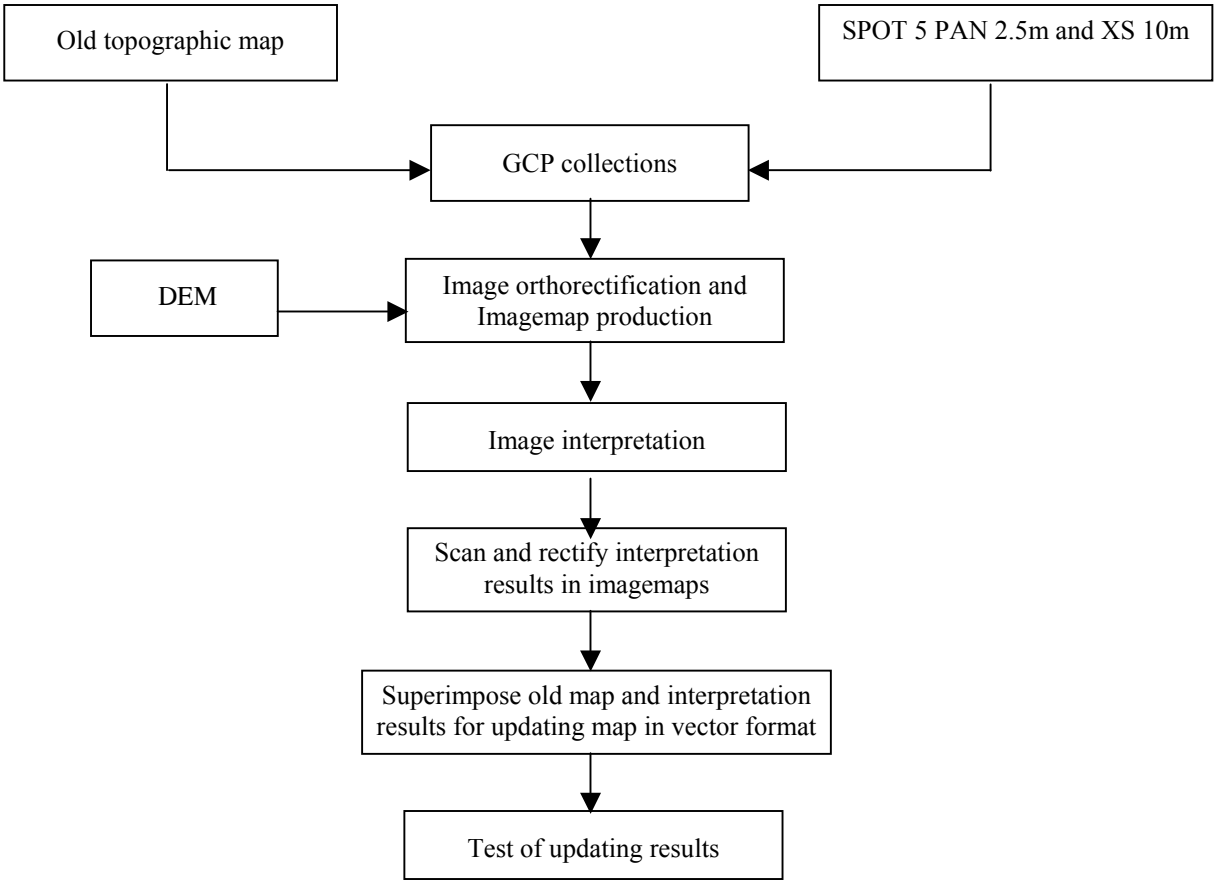

Fig. 1: Map updating procedures using SPOT satellite imagery data

Orthorectification for imagemap production

Orthorectification is an initial step and also a key process in the procedure. Accuracies obtained from this step affected to positions of all features extracted from images.

The orthorectification process have been carried out in the SPACEMAT workshop developed by IGN Espace, France. This workshop consist of separated modules and software integrated together, which allow triangulation and orthorectification of SPOT 5 images using physical model provided by the satellite vendor.

Since SPOT 5 data were delivered depended on acquisition capabilities of the Singapore ground station, the project consisted several blocks of scenes has been setup and gradually expanded during the implementation of the project.

GCP collection and triangulation

Basically, GCP's can be collected from different source, namely, larger scale topographic map, extraction from aerial photography or measuring directly on the ground. In this particular case, GCPs are collected mainly by taking GPS measurements, which will be more secure for the later process for triangulation. Selected GCPs must be located at the clearly visible and accurately identify in images such as cross between roads, paths or streams, corners of the isolate features such as houses. Theoretically, for single scenes or segment 6 points is enough for triangulation applying least square adjustment. However, in fact 10 – 12 points have been collected for each scenes. There are at least one check points designed for each scenes. Moreover, in some areas large scale topographic maps and aerial photography are available for checking quality of orthorectification.

Right after GCP collection process, triangulation of the blocks has been performed. Accuracies obtained of triangulation are maximum errors are 6.7m and minimum at 0.4m.

It is important to realized that both SPOT 5 PAN 2.5m and SPOT XS 10 m are integrated in blocks. As a results, accuracy of triangulation are lower than using only SPOT 5 PAN 2.5m. Test have been carried out for a smaller block of only SPOT 5 PAN consisting of 3-4 scenes and accuracy of less than 4m has been achieved. The reason to integrated lower resolution data of SPOT 5 XS scenes into blocks is to make co-registration of both kind of data to prepare for image fusion in later step.

It is also clear that, distribution of GCP in each scenes as well as blocks are strongly affected to accuracy of triangulation. In the block there are several scenes for which GCP cannot be distributed at designed places because of various reason such as located in sea, outside of the national boundary leading to decrease in accuracy of triangulation for the whole block.

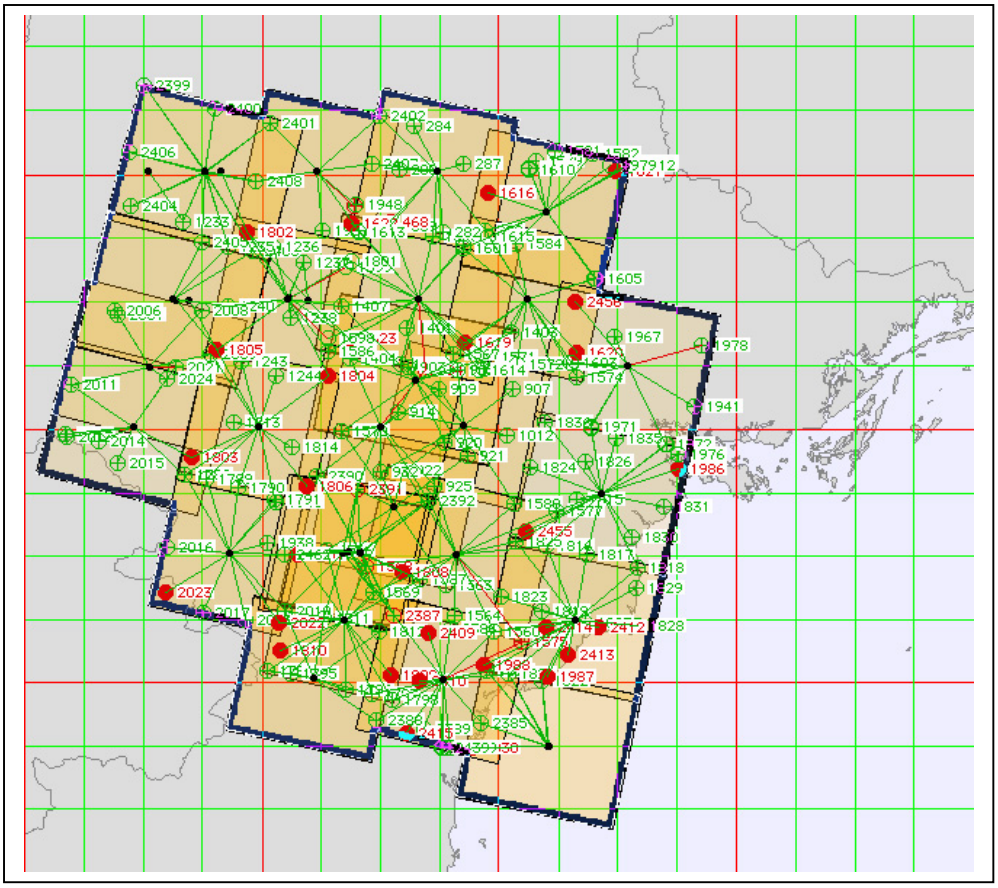

Fig. 2: Block triangulation of SPOT 5 scenes in northern part of Vietnam
GPS points are in Green color, Red color represents homologies points

DEM and Orthorectification process

One of the main advantages of orthorectification with physical modeling is possibility to corrected relief displacement cause by height of terrain.

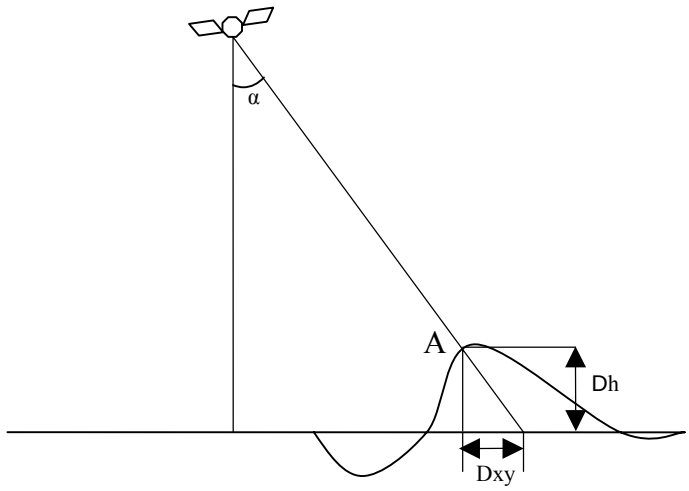

Fig. 3: Relief displacement in SPOT satellite imagery

The effect of terrain undulation to rectification accuracy is expressed in the formula:

$$\mathbf{Dxy} = \Delta h \times \text{tag}\alpha$$

where : Δh is height of points

α is viewing angle

For the SPOT data α is ranging from -26.4^o to $+26.4^o$

Most of DEM in Vietnam were generated from topographic map, therefore DEM's accuracy are suffered accuracies from original topographic map.

The maximum error allowed for topographic map is defined as 1/3 –1/2 interval which are 20 m and 10 m for 1/ 50 000 and 1/ 25 000 scale topographic map respectively. So, it will be approximately 6 – 10 m if generated from 1/50 000 scale map and 3-5m in a case of 1/25 000 scale map. Applying the above formula with maximum viewing angle (26.4o) the maximum rectification errors due to terrain relief are 3m – 5 m and 1.5m – 2.5 m using DEM generated from 1/50 000 and 1/ 25 000 scale topographic map.

Since allowed accuracy for imagemap is 0.4 mm or 10 m in 1/ 25 000 scale map and 4m in 1/10 000 scale map, it is apparent that DEM derived from 1/50 000 scale topographic map are fully acceptable for mapping 1:25 000 scale but may not sufficient for mapping of 1/10 000 scale map while DEM generated from 1/ 25 000 scale are quite acceptable.

After completement of triangulation process, image orthorectifications were performed using DEM generated from 1/ 50 000 scale map. Orthorectified image were compared with checked points to test rectification accuracy. It is found that the greatest errors appeared was less than 8m. This is considered acceptable for updating 1/ 25 000 scale map.

Image fusion

In order to improve interpretability of the imagemap the PAN 2.5 m resolution and XS 10 m resolution were merged together. Several techniques for merging high spatial resolution data with lower resolution multispectral data such as RGB to IHS conversion, Principal Component, and Brovey transform had been tested. Results of image fusion have given a number of comments as follows:

+ Image sharpness of these three methods are rather comparable to each other
+ The RGB to IHS conversion producing fused image with tones are very different from the original SPOT XS image. The other two methods generated fused images with a little change in tones compared to original XS image.
+ The Brovey transform are fastest in term of computation time, since its formula is much simpler.

Based on these comments, it is reasonable to select a Brovey transform for our process.

Natural color composition

As already known, since the original SPOT data do not contain blue band, the false color composition was considered as a standard for SPOT products. This kind of color composite where vegetation appeared in red are not familiar with human perception. Thus, it is expected to created sort of pseudo natural color from SPOT data set. In this project, the method have been set up by the image processing section, in which a pseudo -blue band has been generated based on reflectant characteristics compared to other spectral bands.

Finally, orthorectified image are cut according to map sheet and legend, frame and grid were generated accordingly to created image map using corresponding modules of the SPACEMAT production line.

Visual interpretation for updating map of 1/25.000 scales

The method of manual interpretation have been applied, in which most features were drawn in-house. Field work were conducted afterward for checking, correcting results of in-house interpretation and to identify remaining features. Only changed features and new appeared features are drawn in imagemaps. Beside satellite imagemap, additional data could be used as reference, including:

- Old topographic maps
- Aerial photographs
- Available landuse maps
- Thematic maps such as transportation map, irrigation system and various kind of text documents

Results of the interpretation has shown that most of features of 1/25.000 scale topographic maps can be drawn in imagemap. Interpretability of major groups of features are mentioned below:

Hydrographic features

Hydrographic features such as rivers, streams, lakes or pools can be identified quite easy in the image map relied on its linear shape and distinct different of water surfaces compared to other features. Rivers, streams wider than 2m on the ground can be mapped precisely. It is also possible to detect smaller features located in high contrast areas. Moreover, interpreter can differentiated levels of hydrographic features.

Topographic features

Landslide cliffs, abysses, digging places are interpretable because of their typical appearances with white strip on top and grey strip at bottoms.

Vegetation

Various kind of vegetations are rather easy to identify in the SPOT 5 natural color imagemap. Interpretations of these features can be classified as follows :

+ Forest types: broad-leaf forest are separable from purely needle leaf forest, bamboo forest and other kind of plants based on their typical textures and color.

+ Rank of vegetation: Jungles, sapling forest, plantation forests, shrub and bush are very well distinguish from each other.

+ Rice and other kind of crops are also separable due to their typical cultivated patterns, tones and color.

Residential

This kind of objects has very special textures in the imagemap. It is possible to map urban areas with high degree of details, rural residential areas such as villages with dense or spare of population. Utilization of natural color imagemap allows separation between fire-resistant and non-fire-resistant houses based on color of its roof.

Transportation network

Roads are clearly seen in the image based on its linear shape and its location relative to other features. Almost every kind of roads can be drawn accurately in image including highway, big and small road with earth surface, paths. It is revealed that color image are useful to distinguish between road with hard surface materials such as asphalts, concretes, stones with other soft surface materials. However, it is difficult to separated between those hard or soft surface material road in image but it is has to be identify by field works.

Power line : Power line polls of 220 KV or higher can be identified precisely. The smaller power line cannot be seen in images but field work must be undertaken for its detection.

Potential of features identification for updating 1/10.000 scale map

During implementation of image interpretation step for updating 1/25 000 scale topographic map, it is found that many features can be identified in imagemaps at level of detail of 1/10 000 scale map. These includes hydrographic features such as rivers, streams, rural and urban residential areas, roads, paths, forests, rices and other cultivated areas. Other features have to be difined in the field. Therefore, it suggested that SPOT 5 data (PAN&XS) could be used also to update 1/10 000 scale topographic map. However, this subject will need further study not only on information capacity of data but also geometric accuracy.

Map updating step

In this step, old topographic maps and results of interpretation step are scanned and rectified to common cordinated system. Out of dated features had been already marked in the old map in the previous step. Those data will be superimposed using map editing software such as Intergraph's Microstation. The editor will use various tools of the software to removed non-existed features, modified changed features and add new features with reference to marks in old maps and by tracing already interpreted features.

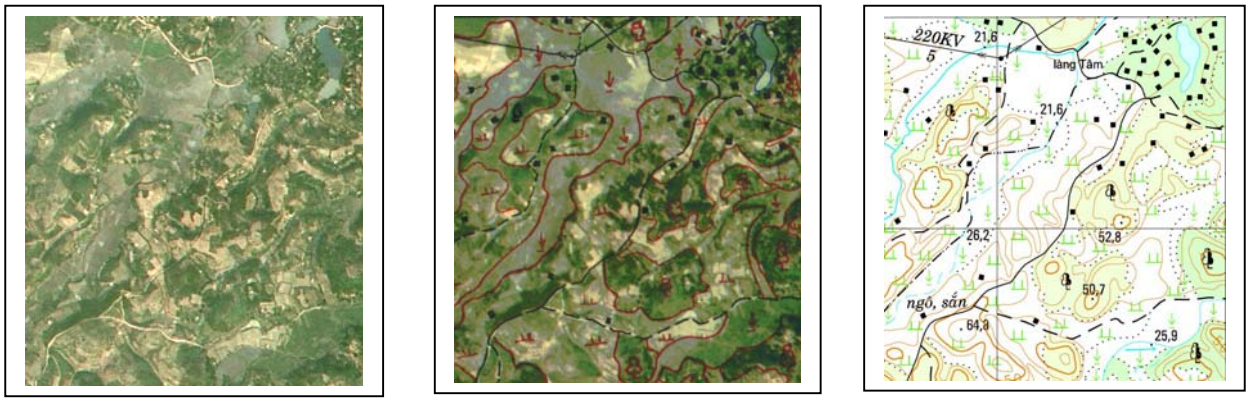

Fig. 3: Example of SPOT 5 pseudo-natural color imagemap, interpretation results and updating map in moutainous area.

Fig. 4: Example of SPOT 5 pseudo-natural color imagemap, interpretation results and updating map in plan area.

Conclusion

Results of map updating project in Northern part of Vietnam has demonstrated that SPOT 5 PAN&XS image data are suitable for updating topographic maps at 1/25.000 scale.

To update 1: 25.000 scale maps, image orthorectification using physical model with GPS measurements for GCP collection and DEM generated from 1/ 50.000 scale map, produces acceptable accuracy.

Merging of SPOT 5 PAN 2.5m and XS 10 m data and pseudo-natural color process enhances significantly interpretabilities of features in images.

The success of this project has indicated that the updating procedure applied in the Remote Sensing Center, Ministry of Natural Resources and Environment are appropriate and effectives.

SPOT 5 data could be used for revising of 1: 10.000 scale map, but orthorectification accuracy need to be improved and surely it will need more field work compare to updating of 1/25.000 scale map.

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