

GEOMETRIC DISPLACEMENT IN A NON ORTHO-RECTIFIED SPACE BORNE IMAGE

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ABSTRACT: Space-borne imageries are becoming increasingly of interest. Professionals typically require accurate digital images to in their spatial information system. A satellite image-map is often compiled and used for such a purpose. It has advantage in that no detail of the terrain is omitted. It can then simply deliver visualized information into the hands of those building urban database. Surprisingly, it has been noticed that the ortho-rectification is often ignored in the image-map production line. In fact, it has been aware that non-ortho rectified images are not sufficient to represent hilly terrain. Ortho-rectification is a rigorous photogrammetric technique to minimize error from relief displacement. Research in recent years has also shown that there is a strong relationship between the precision of the terrain data and the classification accuracy. Motivated by these considerations, this article presents some aspects of the fusion of satellite images with topographic maps on a spatial information system. The interim result also suggests that use of non ortho-rectified satellite images alone may not be sufficient to sharply delineate several man-made feature boundaries. Some aspects of the geometric discrepancies between an original image, and a topographic map are illustrated and discussed.

1. INTRODUCTION

An unavoidable relationship has existed between remote sensing and photogrammetry fields. Although there are exceptions, it has been known that some of the advances in space-borne imaging technology are developed under the photogrammetry theory. Because of its up-to-date information, satellite images have often gained wide acceptance as the optimal database for geographic information systems. On the other hand, a digital vector map is considered as a source to satisfying the accurate information requirements of a diverse group of prospective users (Apaphant and Bethel, 2000). Value of digital images may then be added by integrating with vector data sets of existing digital maps. However, the agreement of feature locations between these two sources must be concerned.

Without the appropriate implementation of digital orthophoto process, a vector map will have never registered systematically with the image. In fact, this issue has been addressed from researchers who deal with image-map production line for years (Moffitt and Mikhail, 1980) (Klimiuk, 1995). Due to the relief displacement from the perspective projection of an image, all features lean outward from the center of the image. This characteristic can be obviously discovered in a large-scale imagery of the hilly terrain. Orthographic rectification is a fundamental concept in Photogrammetry. It is originally employed for converting from perspective projection of arial photographs to orthographic representation. This product is called a map. Digital orthophoto production is recognized as a cost-effective process. Hence it is sometimes skipped in a small-scale mapping production. This approach has made an impact on accuracy of the integrated output. It has been, however, often incorrectly presumed that the mis-registrations are caused by the technical and practical limitations of the combination process. In fact, this statement can be misleading the users. With the current technology, satellite sensors are able to capture very high-resolution image of the terrain. In such a case, the effect from relief displacement cannot be ignored. With the rectification process of the digital orthophoto imagery, all objects are mapped to the surface model and therefore corrected for relief displacement. Orthophoto generation is not the forbidding task. Addressing the displacement problem in systematic manner will yield a coherent product of exceptional value. The image maps can convey a richness of information for GIS users. This paper will then be concentrated on the transformation model required to integrate a digital map with a satellite image. Two types of projections, including orthographic and perspective will be reviewed as well.

2. PROJECTIONS

Projections are the transformation process, which are required when representing the three-dimensional terrain on the two-dimensional space (Petrie and Kennie, 1991). There are two kinds of projections often applied in mapping fields- perspective projection and orthographic projection.

Perspective projection simply emulates the process of human's visualization. Objects in a scene are projected onto a plane through the perspective center. Since the relation between the rays, the image plane, and the object plane are not always orthogonal, this projection produces geometric displacement in an image (Fig. 1). This displacement is found in the areas that the elevation of the ground point above or below the datum. High man-made structures can lean outward from the perspective center. Relief displacement can affect the horizontal accuracy of the placement of features on an image. It is radial from the nadir and increases with distance. The displacement increases as the elevation of the ground point increases, while decreases with an increase in flying height. This characteristic can be simply noticed from an image of linear features, which appear as non-linear features. In order to solve such problem, the orthographic rectification is typically applied. The process constitutes an image on which the detail has been truly rectified.

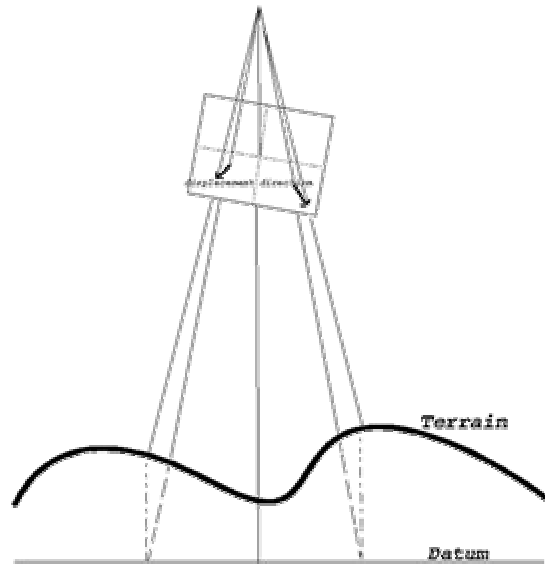


Figure 1: Perspective Projection

On the other hand, orthographic projections are characterized by the perpendicular relationship of the line between the initial point and the projected point and the planes (Fig.2). A projected point can be found by reconstructing a line through the point normal to the image plane. A topographic map is a good example of an orthogonal product. The scale of the map, therefore, will be equivalent to the corresponding horizontal distance measured directly in the field (Moffitt and Mikhail, 1980). For example, if $p(x_p, y_p, 0)$ is orthogonal projected onto the datum of an object space, its projected position will then be $p^*(x_p, y_p, 0)$. This relation can be expressed as follow:

$$(p^* - p) \cdot n = 0 \quad (1)$$

where n is the unit normal vector to the plane from the origin.

3. ORTHOPHOTO GENERATION

A digital orthophoto is a transformed product analytically rectified to eliminate distortions arising from topographic relief. As previously explained, because of the perspective aspect, image features can be displaced from their true horizontal location. If a feature can be located at the true position, it will be sited in its correct horizontal location as well. This principle is applied to create orthophotos. The resulting image will behave as a planimetric map in all respects except that it shows pictorial features.

There are several different orthophoto generation methods. Most methods definitely can produce truly rectified photo imagery at a certain degree. For the sake of completeness, the pseudo- code of a ortho-photo generation method will then be reviewed here. Since it is a general approach, it can be applied for both time independent and time dependent image models. There are three steps to the procedure as follow:

- DEM Processing
 - Obtain or measure DEM.
 - Fix extent of orthophoto (in ground units), Fix the interval between orthophoto pixels (in ground units).

- Differential rectification
 - Determine exterior orientation parameters of an image.
 - Interpolate a height of an examined point from DEM.
 - Compute image coordinate by collinearity equations.
 - Compute pixel coordinates by 2D transformation.
- Interpolation of intensity values
 - Interpolate a gray value by any well known interpolation.
 - Write output gray level in the output file, go to next point in ground space matrix back to earlier step “Interpolate a height of an examined point from DEM”.

It can be noticed that the process is described above implies that elevation data is an important factor when rectifying an image. The result provides an image that is free relief displacement, and all features are planimetrically correct. If required, the verification of agreement may be accomplished by the comparing the calculated location of control points in the output image with actual position.

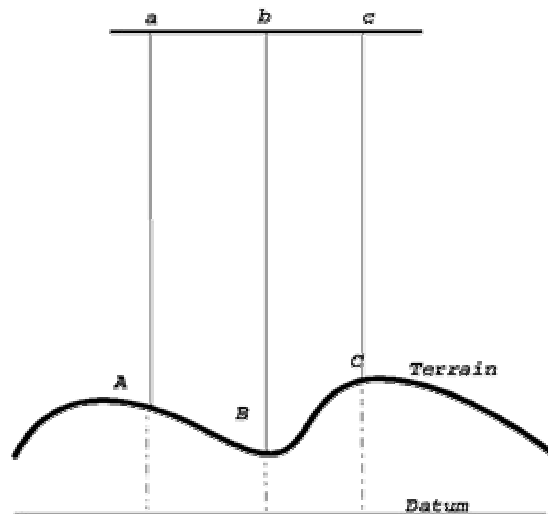


Figure 2: Orthographic Projection

4. DATA INTEGRATION

Much of the value of satellite images may be increased by overlaying existing line maps of the corresponding area. This value-added product is often called an *image-map*. As mentioned before, the projection method hidden in these two data sources are originally different. Unexpected pitfalls can then be associated with this integration, if it is not applied appropriately. A map is an orthogonal representation, while a satellite image is a reproduction of the terrain using perspective projection. The projected points of the points lying at different elevations will not correspond to the same relation to one another as the original points. If a satellite image is to be directly used as a map substitute, then the effect of relief displacement and scale variation must be aware, especially where the scale of the image is large and there is relatively high terrain relief. Without the identical projections, the geometric relationship between features in a satellite image and a vector map will be very sophisticate. In such a case, linear features may be simply represented as non-linear features. The difference of feature locations between in a LANDSAT7 image and in the corresponding map can be appreciated by a study of Fig. 3. It can be noticed that a road (a gray line) in the hilly area does not register exactly and uniformly with the one (a red line) in the map. This is because vector data sets were acquired from photogrammetric compilation while the satellite image is the perspective representation. It indicates that the different types of projections have made an impact on the mis-registration, accuracy, and etc.

The intent of the integration exercise then becomes the editing of existing vectors in the problematic areas. Fixing existing vectors is not a simple task. Furthermore, it contradicts mapping convention to directly displace new features in order to maintain consistency by using this approach. Instead, addressing the integration process in systematic manner will yield a coherent product of exceptional value. The effect of relief and tilt displacements in the positions of point on photographs is caused by the perspective nature of an image. In order to combine the

information of a line map with a satellite imagery, the image must be manipulated systematically to remove the perspective aspect and the tilt effect. To fulfill this objective, the orthophoto generation method mentioned previously can be applied here. The image maps would then be able to convey a richness of information, which is heretofore unsurpassed for further analysis.

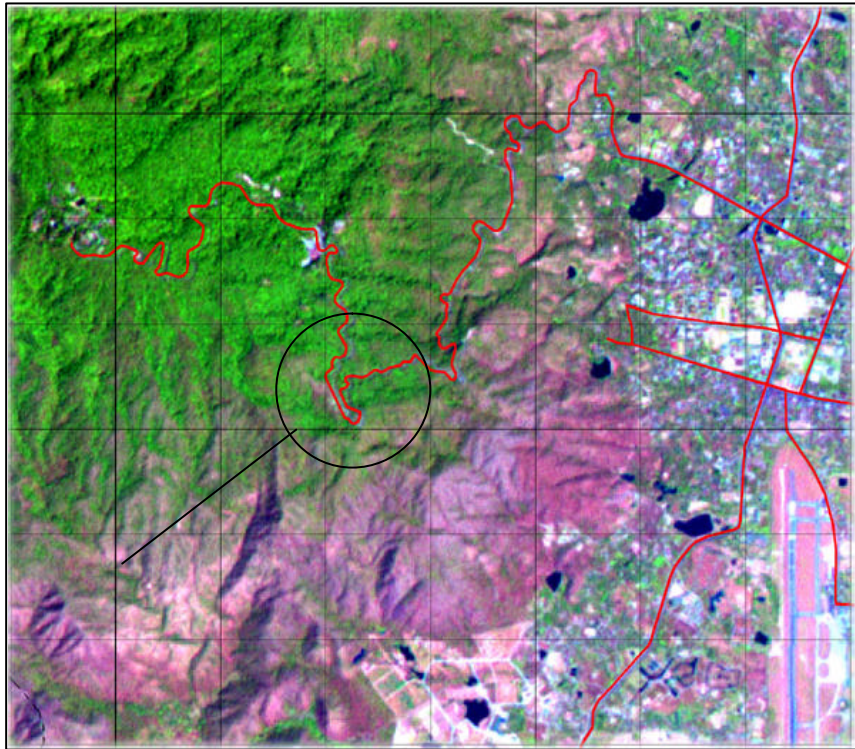


Fig 3: The geometric discrepancies of feature locations in an image map

5. CONCLUSIONS

With its details and high accuracy of satellite image map, this value-added product has been widely used over the last decade. A satellite image is a reproduction of the scene using the perspective projection while a map is the orthographic product. The relief displacement effect can be noticeable on a large-scale image of non-smooth terrain. Since currently high-resolution space borne images are simply feasible and accessible, the integration should then be established theoretically correct. Satellite image should be orthographically rectified before the integration. Otherwise, the value-reduced product should be called instead.

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