Orthotransformation of Satellite Scenes

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GROUP: TMSS
PART II: EXTENDED VERSION

January 14, 2022

Abstract

There are different methods that could be applied to generate orthotransformed images. In this paper we consider main problems which could occur while using this methods and build up a sustainable algorithm which is supposed to overcome such obstacles.This paper overlaps main approaches which are commonly be used in orthophoto rectification represented by polynomial, projecting and differential algorithms respectively. Considering polynomial and projecting algorithms we obtain analytical transformation between real image and rectifiable photo without considering the geometry and orientation of cameras whereas differential model approximates reality of the imaging process by means of collinearity equations and corrects for relief displacement. This paper compares methods which are represented above weighting up benefits and drawbacks in comparison with each other.

1.INTRODUCTION

Orthotransformation is the method which provides elimination of sensor tilts in the way of terrain terrain distortion. This information is necessary for GIS services in order to obtain data which could directly be used in determination of certain locations, measure distance, compute areas and get other useful information regarding certain location. However, most of such kind of images are taken by imaging satellites. As the resolution of images are being increased every time so that there is a persistent need in processing such images with new methods.As mentioned before the most complicated scenes are urban locations which are settled with high density of buildings which could not be easily reprojected. In this paper, methods of orthotransformation will be observed and discarded respectively. Main methods of rectification and preprocessing are recreated below.

2. SATELLITE PROCESSING

The first question is why should be orthocorrection be carried out whether it could be also distinguished in image and how will distortion of the processed image deteriorate quality of it. If we measure a positional properties of an image or combination of different time image the correction is needed.

To proceed the orthotransormation the supervisor should possess the following data.

- A satellite image of the delivery formats (GeoTIFF and etc.)

- RPC [1]data to the images, snapshots

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[1]Rational polynomial coefficients

- Information about the relief in the form of (DEM) [2]

The most acceptable way to process data for orthocorrection is the geometry transformation at the moment of image registry. Ordinary method is based on photogrammetric model which is respectively based on digital terrain model (e.g. DTM). The satellite camera model in the form of generalized approximation functions (rational polynomials) can be considered one of the generalizing models used instead of strict models. It expresses relations within the objects and coordinates of the image using the coefficients. This method is called (RPC). For further processing the terrain file is needed in raster format (e.g.DEM [3]). The data about height and angles could be obtained as a result of terrain measurements through radars or from other RPC's.

3. METHODS OF PROCESSING

This paragraph describes methods of processing and generating othotransformed images: First of it is forward projection while the other uses backward method of reprojection. Considering the forward projection each pixel in source image is projected to orthotransformed image and the corresponding determined with intersections of from the center through the image point with the three dimensional ground surface defined by the DSM [4]. In backward projection, each pixel in the orthotransformed images takes its pixel value from the source image using the collinearity condition and the object space coordinates X, Y, and Z of the corresponding DSM cell. In forward projection, even though the Exterior Orientation Parameters (EOP [5]) of the source image and DSM are available, the object point corresponding to each image pixel cannot be determined directly because three dimensional ground coordi-

nates are calculated using two dimensional image coordinates and EOPs. For this reason, an iterative process is required to find the DSM point corresponding to a pixel in the source image, and two cases are possible (Figure 1). In the case in which the slope of the ray from the source image is larger than the slope of the ground surface, the convergence of the algorithm is guaranteed (Figure 1 (a)); however, in the case in which the slope of the ground surface is larger than the slope of the ray from the source image, this iterative process may not converge (Figure 1 (b)). Even though the first case (Figure 1 (a)) is more common, especially with satellite imagery, we must avoid any possible problems due to non-convergence. Another shortcoming of forward projection is that some missed pixels may appear in the resulting orthotransormed images.[1] The picture of following methods are displayed below.
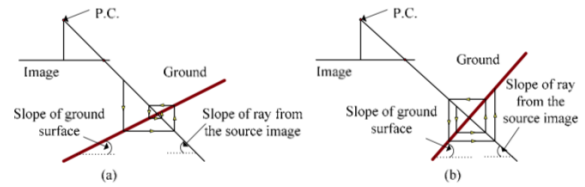

Figure (1) Ground point search method

Differential rectification differs forward projection in the way that backward projection goes from the object space to the image space using the object to image transformation[1]. However, the ground surface slope is not a serious issue, and furthermore, an iterative process for finding corresponding ground points is not required for frame camera imagery. In Figure 2, target orthotransormed images are generated through backward projection without an iterative ground point search or missed pixels in the resulting images. Backward projection, however, does require another iterative process for line scanner imagery because the EOPs of each

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[2]Digital terrain model
[3]Digital evaluation model
[4]Digital surface model
[5]Exterior orientation parameters

scan line change continually during image capture. This issue is discussed in the section in which new proposed methods are introduced.

4. PROPOSED METHOD

The main method to generate orthotransformed images is z-buffer algorithm. In order to visualize objects which are non-transparent. This problem is also know as Hidden Surface problem and can be solved using this algorithm. This image space method is based on pixel to be depicted on 2D. It compares surfaces depth of each pixel position on the plane surface.The main advantage of this method is that it could use large number of polygons to be executed and can be effectively applied either to transparent object or to an opaque ones.

photo/z-buffer.png

Figure (2) Z-buffer method algorithm

But the are many conses which occur. Z-buffer algorithm falsifies visibility with narrow vertical structures and it is called the M-portion problem which can be solved by adding additional points to near the vertical structures and etc. However, there are to more ways how the orthotransformed images could be precisely solved: (The following methods are described below).

- 1 Adaptive Radial Sweep Method

- 2 Spiral Sweep Method

This methods are dependent on several parameters which are the line displacement that is connected the center of perspective and observation angle.The top and bottom of vertical structures are being reprojected to the same place if the terrain is not distorted. However,in perspective projection upper and lower parts of structures

are projected as two pixels. This bias is made in radial direction. This bias leads to so called occlusion on perspectives. This occlusion can be easily discovered by investigating the feasibility of biased angles. Generation of such projection is depicted below.
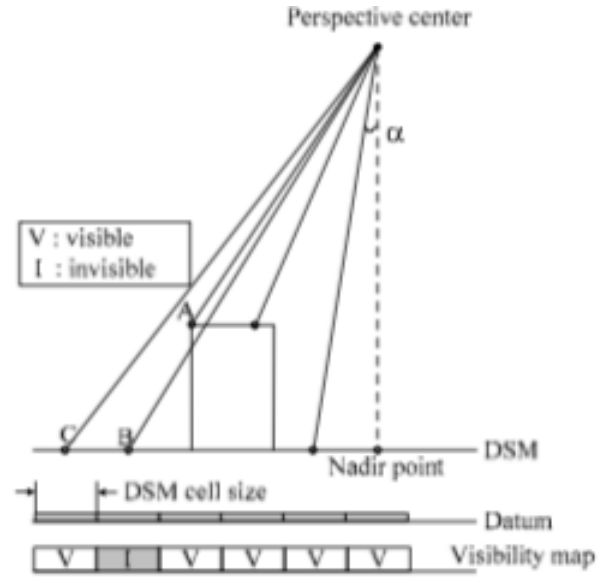

Figure (3) Orthoprojection using ABM [7]

Nevertheless, The are some ways to remove this occlusion as a result of bias. If (DTM) is sorted is being processed as height values though results can be elaborated with z-buffer method. Orthophoto pixels are filed in the order of heights. This is depicted in Figure(4). (DTM) cells are sorted in the order of heights and the backward projection is done exactly the same way 5-th cell in the picture has the same pixel as 2-nd one. In order to detect pixels of projected image new proposal could be used: Using additional massive of the same dimension as the initial image has to count.
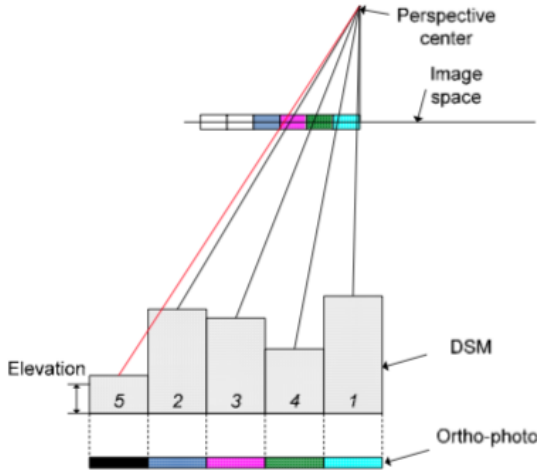
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[7] Angle Based Method

Figure (4) Ortoprojection with (DEM) sorted

The other way of moving The angle based methodologies introduced by Habib et. al. (2005), after some modifications, can be used for occlusion detection when using imagery captured by line cameras. As mentioned previously, a line camera scene has multiple exposure stations; therefore, for such a scene, there are multiple nadir points. After identifying the exposure station for a given object point, we can use the angle based technique to check whether this point is visible. To evaluate the visibility of a given point, a search path, which is defined by the projection of the object point onto the orthophoto plane and the corresponding nadir point should be investigated.

5. POLYNOMIAL RECTIFICATION

There are three main methods which are created and commonly used in image processing systems. And the first method which is going to be discussed is projecting transformation.The following method is held by polynomials between rectified image and original ones. This method is represented within following equations.

$$x = x'^T A y' = f_x(x', y') \qquad (1)$$
$$x = x'^T B y' = f_y(x', y')$$

where

- 1 **x**, **y** are coordinates of original image respectively

- 2 **x',y'** are coordinates of rectification

- 3 **A**, **B** are matrices of polynomials

This method overlaps distortions of the image relative to a dense set of control points. The order of the polynomial depends on the number of control points available. The more control information one has, the more accurate the result of the rectification will be[11]. This approach is completely independent of the geometry of the imaging sensor, so it can be used both for satellite images and aerial photographs.
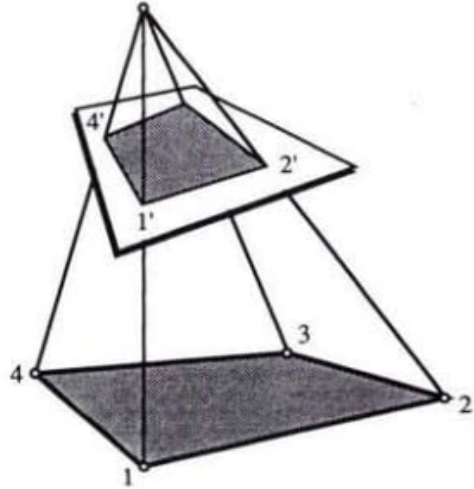

Figure (5) Projecting relationship between an object and the the image by 8 parameters

Due to the polynomial transform, the original image is shifted, rotated, scaled, and squeezed so that it fits best to the given reference points. This is the reason why the method is most often used for satellite images, whose geometry and distortions are sometimes difficult to model. Moreover, the relief displacement due to the topography of the Earth is relatively small compared to the flying height of the

satellite and does not influence the result significantly.

However, Polynomials are easy-to-use for rectification.This could be thoroughly inconvenient in direct rectification in preprocessed, transformed images because of incorrect relief displacement. Although, the main benefit of polynomial transform is that all distortions of image are correlated simultaneously with small residuals.

The main points of polynomial rectification

- Model simplicity and computationally profitable

- Independencies of the sensor geometry and platform

- Accuracy is less than rigorous models in general

- For the inexperienced user a high-order polynomial may seem to provide a perfect fit at the reference points as the residuals are small.

- Polynomial expressions are characterized by a great capability for absorption of accidental distortion

6. PROJECTING TRANSFORMATION

The projective transform describes the relationship between two planes. It is defined by eight parameters, which can be derived from four object points lying in a plane and their corresponding image coordinates. The following formulae describes the algorithm clearly(2).

$$x = \frac{a_1 x' + a_2 y' + a_3 z''}{c_1 x' + c_2 y' + 1} = f_x(x', y') \quad (2)$$

$$y = b_1 x' + b_2 y' + b_3$$

Where x, y are coordinates of the original image; x', y' are coordinates of the rectification; and a1, a2, a3, b1, b2, b3, c1, c2 are projective parameter. The algorithm is represented in *Figure(5)*.

Where y is given in the flying direction and x represents the pixel in a scan line. Compared to (2), the elements of exterior and interior orientations are implicit in these parameters.
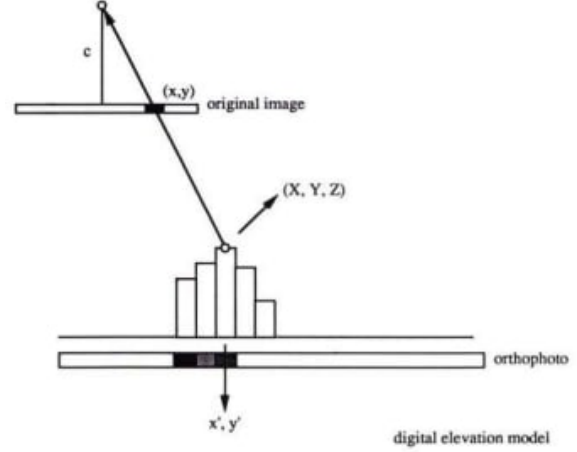

Figure (6) Orthophoto raster for DEM point

Nevertheless, this method has little practical significance for satellite scenes. The beneficial part of this algorithm is mentioned below:

- This method is typically used to rectify aerial photographs of flat terrain or image of facades of buildings(due to earth curvature so it can be related to satellite scene)

- Absence of interior and exterior orientation(not required for its implicitly)

- This method has little practical significance for satellite sensors, but could be applied for airborne line scanners.

7. DIFFERENTIAL RECTIFICATION

A digital elevation model (DEM) is needed to correct for relief displacements in the image. It is assumed that the DEM is stored in the same format as the digital image, Le., as a raster of digital values, which in this case expresses elevations instead of densities and are 16 bits long (compared to 8 bits of gray value). The DEM has

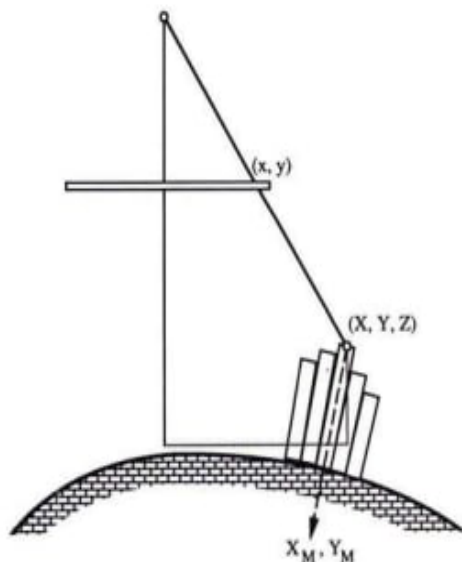to be related to the map projection of the resulting orthophoto[14].

Figure (7) Correction curvature of the Earth applying DR [8] to Cartesian system(X,Y,Z)

This method every pixel of the or-thophoto has to be processed separately, computation time is a major concern. It can be largely reduced by optimizing the image transformation. Multiplications must be avoided and substituted by simple additions. This is done by taking advantage of the incrementation of pixel 10-cations at the resulting image (orthophoto) *Figure(7)*.

8. METHOD COMPARISON

Comparing the height based ray tracing method proposed in this study is quite fast compared to the other effective true orthophoto generation methods, such as the modified z-buffer method and the angle based ray tracing method.The processing performance of each method is show in Picture(5). We don't consider Modified Z-buffer
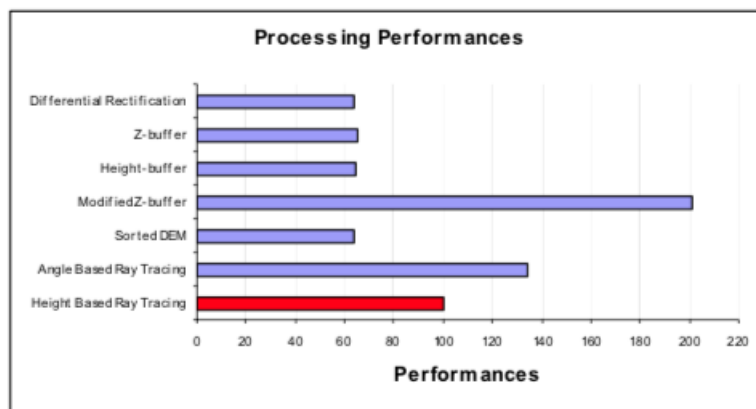
Figure(5) Processing time of the methods testing

As we obtained results the proposed method is the most easy-to-use method in front of others. Here are some performance stats in *Table №1*

Methods frequently used			
Solution	Differential rect	Polynomial rect	Projective rect
p2	1.06e+00	1.05e+00	2.62e+00
p4	1.05e+00	1.01e+00	2.71e+00

Table №1 Residuals in image with the test dataset(by Intermap Technologies)

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[8]Differential Rectification

- Both the rational function models and the polynomial model (i.e., p2=p4=1 case) can reach the accuracy around 1 pixel.

- Both the rational function models and the polynomial model (i.e., p2=p4=1 case) can reach the accuracy around 1 pixel.

- In general, the cases with rational components are slightly better than the polynomial models.

- The fitting accuracy of the cases with four-degree is very close to those with six-degree. It is understandable since the aerial photogrammetry data set may not involve high order distortions.

In addition, the quality of the output image is better than that of any other method, with the exception of the angle based ray tracing method. For this reason, the height based ray tracing method is recommended for true orthophoto generation using scenes captured by line camera.

9. CONCLUSION

In conclusion, genearating correct orthophoto images is quite complex problem which demands time and computational resources

The way the image could be processed depends on the landscape and structures such as buildings, thin vertical structures and density of such elements. The ordinary method to process simple non-uniform scale is to use z-buffer algorithm. However, proposed methods of adding reference points will solve the problem with complex landscapes. The comparison of three different approaches commonly used in image processing systems proved that a differential rectification that corrects both for relief displacements and camera distortions yields the best results, and should be used both for aerial and satellite images. This method not only generates orthophotos, but it actually finds the gray value of each DEM point and stores it at the same location. Thus, a digital surface model is created which contains elevation, density, and maybe other attributes (such as exposure, slope, temperature, etc.) at each position. These different layers of raster data are given in a georeferenced, orthogonal projection, and can easily be overlaid by vector data stored in the GIS. Moreover, both orthophoto and DEM can be created at the same time by digital image matching.

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