

# ANALYSIS AND THE SOLUTIONS FOR GENERATING A TRUE DIGITAL ORTHO PHOTO IN CLOSE RANGE PHOTOGRAMMETRY

M. Shariat<sup>a\*</sup>, A. Azizi<sup>b</sup>, M. Saadatsersht<sup>b</sup>

<sup>a</sup>Dept. of Geomatic Engineering, Faculty of Engineering, University of Tehran, Iran - mashariat@ut.ac.ir

<sup>b</sup>Centre of Excellence for Disaster Management, Dept. of Geomatic Engineering, College of Engineering, University of Tehran, Iran - aazizi@ut.ac.ir

**KEY WORDS:** True Orthophotos, Occluded Areas, Grey Shade Interpolation, Histogram Matching, Mosaic, Close Range Photogrammetry

## ABSTRACT:

Digital orthophoto is an image where the relief displacements and the camera's tilt have been removed. So it is an efficient, inexpensive and accurate approach for purposes such as evaluation, analysis or measurement of the objects presented in the images. For this reason digital orthophoto has occupied an important place in spatial database in GIS. The traditional orthophoto is based on Digital terrain model and it does not include the man-made objects. Therefore, the orthophotos of urban areas do not have satisfactory accuracy. True orthophoto generation by using the digital surface model in rectification process and detecting occluded areas through the visibility analysis is the only solution. True orthophoto can be produced from close range as well as aerial and satellite images. In this paper, to simplify the true orthophoto generation process several close range images of a cubic object are used with a regularly spaced grid DSM. In close range Photogrammetry the distance between camera and object is small and as a result the occluded areas are extensive. Therefore, the occluded areas detection method must be efficient. In this research work the height-based raytracing method is used to detect the occluded areas. To restore the information of the occluded areas the seamless automatic mosaicking considering histogram equalization of images is applied.

## 1 INTRODUCTION

Today with increasing importance of GIS, particularly in urban areas, the demands for digital orthophotos with high details and greater accuracy are growing. Digital orthophotos provide spatial and spectral information and have many applications such as measurable virtual reality. There is not any relief displacement in orthophoto and there are consistent scale in it that cause to be similar to the maps. Since in the traditional orthophoto production, DTM and aerial photographs of urban areas are used and DTM does not contain man-made objects such as buildings, bridges etc., and also because of the perspective geometry inherent in the images, these features do not locate in their true positions and hence a geometrical error occur in orthophoto. This problem shows itself clearly if the vector data of man-made objects is superimposed over the corresponding orthophoto. Moreover, the man-made objects in the image, produces occluded areas so that the quality of orthophoto deteriorates. Therefore an orthophoto that is geometrically complete and accurate is needed. This demand is fulfilled with the so called true orthophoto that is produced using the DSM. But when a DSM is used the double mappings occur. These occluded areas must be filled using the neighboring overlap images and a mosaicking procedure is required.

In this paper, close range images of a cubic object are used. Four images are taken from different direction by using a non-metric camera. One image is considered as a master image and others are slave images. For recovering the position and orientation of the camera during the exposure time some retro-reflective targets as ground control points are used.

The final accuracy of the ortho-rectified image may be improved by incorporating self calibration strategy. After the computation of the exterior orientation and self calibration parameters, the occluded areas are detected using the raytracing

approach. In the final stage, the image segments are stitched to form a uniform image.

The sections that follow, after a brief review of classical method of ortho-rectification, the above mentioned procedures for generating true ortho are described and the final result is presented.

## 2 TRADITIONAL ORTHOPHOTO

Two points with the same location and different height in the object space will project at two different locations in image space because of using the perspective projection. Differential rectification is the process of removing these relief displacements using the DTM, inner and outer orientation parameters of image. The rectification can be done in two ways: Forward projection and backward projection:

In forward projection for each pixel of master image, using DLT equations, the ground coordinate is calculated. If the ground coordinates of the corner points and the pixel size of the orthophoto is known, the pixel coordinate in the orthophoto is determined. In this way the three dimensional ground coordinates of each image pixel is calculated using two dimensional image coordinates and hence an iterative process is required (Bang, 2007). Moreover, the regularly spaced points in the image are projected to a set of irregular spaced points, so they must be interpolated into regular points. To avoid aliasing problem, the distribution of the regular points in object space should satisfy the sampling theorem.

Figure 1 shows the basic geometry of the forward projection approach for ortho rectification.

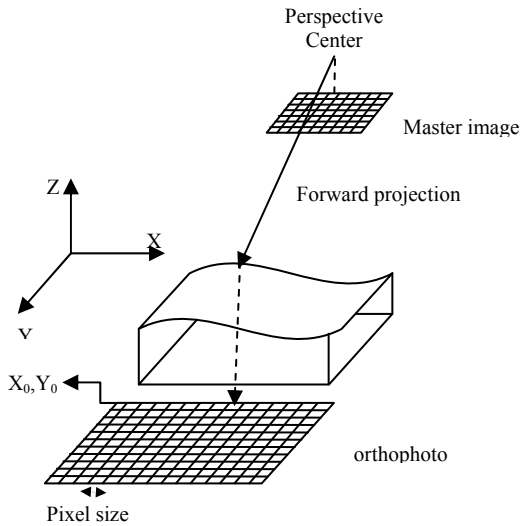


Figure1: Forward projection.

In the backward projection approach, the ground planimetric coordinates are determined using the ground coordinates of the corner points and pixel size of the orthophoto, then Z coordinate is extracted from the terrain model. Each pixel in the orthophoto is subsequently projected back to the image space using the DLT equations. Each pixel in the ortho space takes its gray value from image pixel through the resampling (Figure 2).

In this way there is no need to an iterative process and the interpolation is only done for each orthophoto pixel so if the orthophoto pixel size is optimum there will not be any missed pixel. Therefore the backward projection is often preferred.

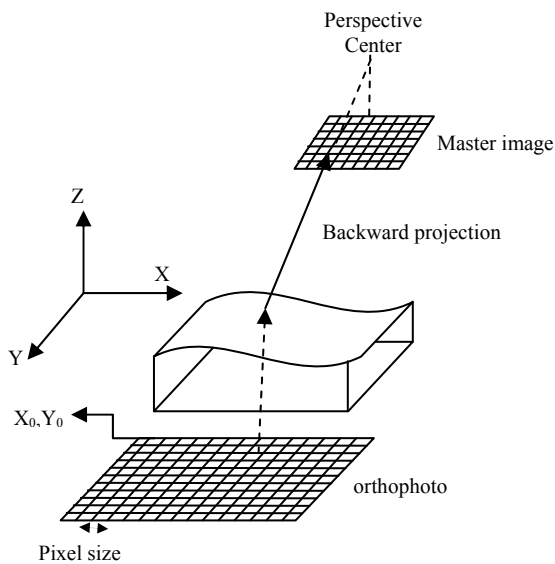


Figure2: Backward projection.

As mentioned before, the traditional orthophoto which is generated based on a terrain model is not a complete and geometrically correct image data base in urban areas, because of the fact that the terrain model does not include man-made objects such as buildings and bridges. So when we use the terrain model in orthophoto generation these features do not locate in their true positions and only those features that are in

level with the terrain locate correctly. Therefore, the relief displacement of man-made objects cannot be eliminated. This generates the building leaning phenomenon and hence the walls will be visible. This leads to the occlusion problem (Figure 3).

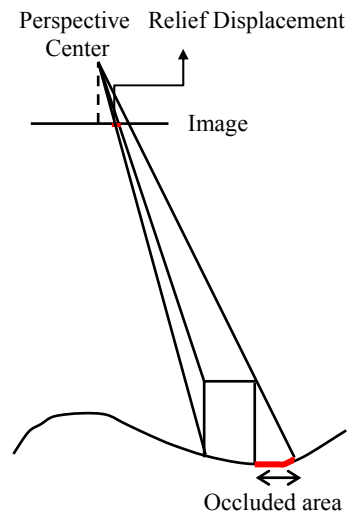


Figure3: Occluded areas due to the relief displacements of man-made objects.

These problems make it impossible to measure the correct position of man-made objects in orthophoto. The solution is the generation of true orthophoto. Figure 4 shows an orthophoto of a cubic object generated by classical approach.

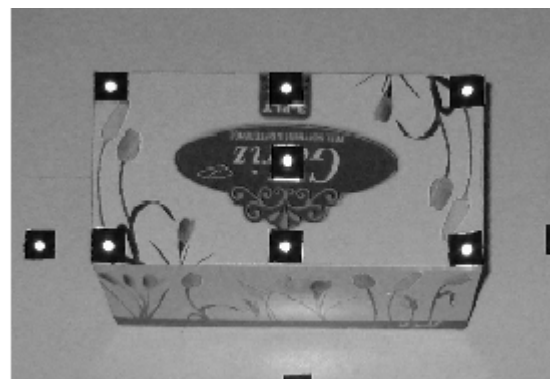


Figure4: Traditional orthophoto.

### 3 TRUE ORTHOPHOTO

To generate a true orthophoto, the 3D positional information of the man-made objects is projected perpendicularly into a plane parallel to the orthophoto plane. Thus for producing the true orthophoto, the DSM of urban areas that include buildings, bridges and any other object must be incorporated.

Even when the DSM is used to remove the geometric effects of relief displacement, the problem of occluded areas will still remain. The occluded areas are replaced by the gray values of that features and hence the so called "double mapping" or "ghost image" occur.

The reason for this is that when the occluded areas behind a building are rectified, they will intersect the building in the projection process. Therefore the gray values of building are

used to fill the occluded areas. This is illustrated in Figure 5. Both points A, B have the gray value of point B.

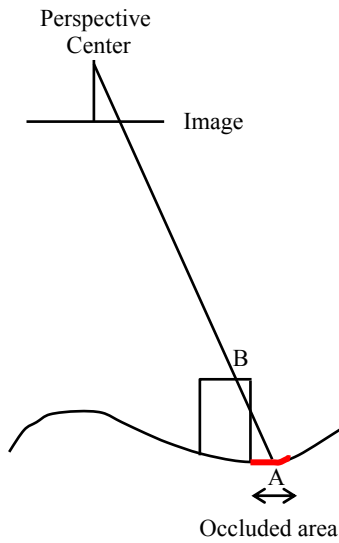


Figure 5: Double mapping.

To restore the occluded areas, it is necessary to detect them and use neighboring overlap images to extract the information of these areas for replacing them in the orthophoto.

In the aerial Photogrammetry the relief displacements can be decreased by using images created with a normal angle lens shot from a higher altitude, but in the close rang photogrammetry this condition cannot be easily fulfilled and hence large relief displacements occur. So the occluded areas detection will be time consuming and an efficient method must be used.

### 3.1 Occluded areas detection

The detection of occluded areas is based on the visibility analysis. If a ray from the output pixel intersects other features in its path from DSM to perspective center, it is marked an occluded pixel and filled with black color.

In this paper the height-based raytracing method is used for detecting occluded areas (Bang, 2007). In this method, for each pixel, the projection of ray onto the orthophoto plane (from the nadir point to the pixel in the orthophoto space) is considered as a search path. For testing the visibility of each pixel, the height of the ray is compared with the height of some points along the search path in specific intervals. If at least one point is found with higher height than the ray height, the pixel will be marked as occlusion. Figure 6 shows the principle of the height-based raytracing method.

### 3.2 Mosaicking

In this stage the information of the occluded areas are restored using the neighboring overlap images. In producing the true orthophoto each occluded pixel in image have to be restored with pixels in neighboring overlap images. So we must know which pixel in which image must be used. This selection is based on one or a combination of the following factors (Schickler, 1998):

- Distance to nadir: smaller distance to nadir will result in a smaller relief displacement for features not modeled.

- Distance to occluded areas: smaller distance to occluded areas will result in a disharmonious image.
- View angle: narrowest view angle will avoid smearing problems.

When the images are mosaicked the differences between radiometric characteristics of each image patch make seam lines visible. Consequently, the histogram matching is inevitable to equalize the radiometric responses of the image patches in order to achieve a true orthophoto with high quality.

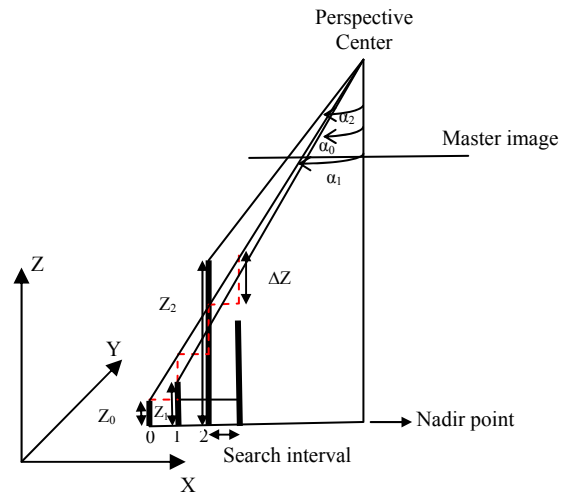


Figure 6: The principle of the height-based raytracing method for occluded area detection.

## 4 EXPERIMENTAL RESULTS

In this paper four close range images from four different stations around the test object are used. The camera positions are selected in such a way that by combining the images no occluded areas remain. The positions of the stations are shown in figure 7.

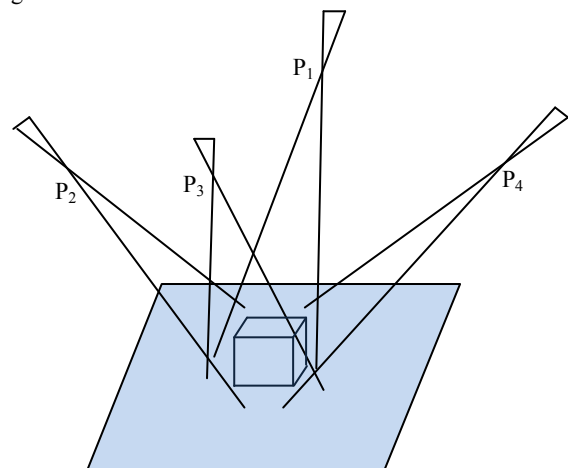


Figure 7: The positions of camera stations.

Some retro-reflective targets are used on the test object to determine the position and orientation of the camera. The DLT equations are used as a camera model.

First the histogram of master image is considered as reference and the other histograms are matched to it. Then the orthophoto of all images are produced with a regularly spaced grid DSM and using the backward projection approach. As mentioned before, during the ortho-rectification, the occluded areas are replaced by the grey values of the features and double mapping occurs. Figure 8 illustrates this problem. As shown in this Figure, in close range case the occluded areas are comparatively extensive.

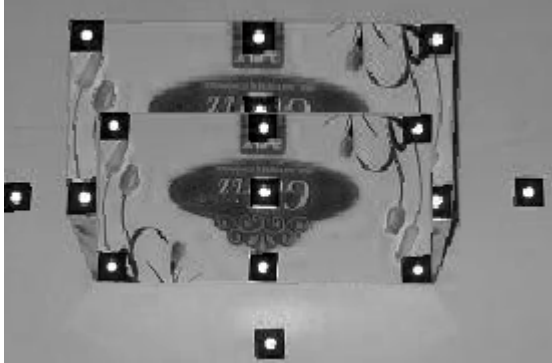


Figure 8: true orthophoto with double mapping due to the use of DSM.

The occluded areas of the orthophoto are detected by using the height-based raytracing method. This process is performed for all images. In this method the optimal search interval should be determined based on the orthophoto pixel size so that the visibility of all pixels analyzed. The output of this process will be orthophotos with occluded areas appearing in black color. Figure 9 indicates the detected occluded areas for the test object. To obtain the final true orthophoto the mosaic procedure must be done. The final true orthophoto of the cubic object is shown in figure 10.



Figure 9: true orthophoto with occluded areas marked black.



Figure 10: Final true orthophoto of the test cubic object.

## 5 CONCLUSION

Digital true orthophoto generation in urban areas has most importance. The basic challenges are the occluded areas and double mapping. Therefore, the true orthophoto is generated from four close range images of a cubic object. In close range case the distance between camera and object is small and as a result the occluded areas are extensive. So an efficient method must be considered for occluded areas detection. The height-based raytracing method is applied that is not time consuming and the result of that has high quality compared to the other methods. The histogram matching and mosaic procedure is done to restore the occluded areas. Experimental results indicate that a smoothing process is still need to make the seamlines completely invisible.

## REFERENCES

- Amhar, F., Josef, J., C. Ries (1998). The Generation of True Orthophotos Using a 3D Building Model in Conjunction With a Conventional DTM, *International Archives of Photogrammetry and Remote Sensing*, vol.32, Part 4, pp. 16-22.
- Bang, Ki-In., Habib, A., Kim, C., Shin, S., (2007), Comprehensive Analysis of Alternative Methodologies for True Orthophoto Generation From High Resolution Satellite and Aerial Imagery, *American Society for Photogrammetry and Remote Sensing*, Annual Conference, Tampa, Florida, USA, May 7-11.
- Braun, J., (2003). Aspects on True-Orthophoto Production. Proceedings, 49th Photogrammetric Week, pp. 205-214. Stuttgart, Germany.
- Ettarid, M., Ait M'Hand, A. and Aloui, R (2005), "Digital True Orthophotos Generation", *Proceedings of the FIG Working Week*, Cairo, Egypt, April 16-21,11 p.
- Schickler, W., Thorpe, A., (1998). Operational Procedure for Automatic True Orthophoto Generation, *International Archives of Photogrammetry and Remote Sensing*, vol. 32, Part 4, pp. 527-532.
- Yamada, K., Odaa M., (2004). Discussion on the Generation Method of Simplified True Ortho at the Urban Area Using The Area Sensor Type Digital Aerial Camera "DMC", *International Archives of Photogrammetry and Remote Sensing*, vol.XXXV-B3, pp. 942-947.