A Review of True Orthophoto Rectification Algorithms

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Abstract. Orthophoto is one of the most important basic geographic information products. Because traditional orthophotos use incomplete surface information for digital differential rectification, there is mutual occlusion between images, which is difficult to meet the current large-scale urban mapping requirements. With the rapid development of photogrammetry technology and the increasing demand for high-precision graphics, the true orthophoto has become a major research hotspot at home and abroad. This paper expounds the development of the true orthophoto rectification, summarizes the relevant algorithms for the true orthophoto production, and points out the core problems and future development of the true orthophoto production. Through the summary and analysis of the image rectification algorithm, the image occlusion detection, shadow compensation and other issues are proposed. The morphological filtering algorithm is used to identify buildings in densely populated areas, and the PCNN model method enhances texture features, and combing the deep learning for shadow compensation, in order to optimize the actual image rectification algorithm for existing images.

1. Introduction
Orthophoto is the most widely used and basic image product in geographic information products [1], and it is both a precise map and a beautiful image [2]. In practical applications, orthophotos are directly used as small and medium scale maps, updated earth surface maps[3], monitoring volcanic disasters in Nisilos, Greece[4], measuring changes in native pine forests in Scotland[5], three-dimensional urban scenes reconstruction[6], village survey[7], land planning, precision agriculture, desertification monitoring, land use survey, rural housing registration and other fields[8]. Traditional orthophotos are differentially corrected using a 2.5-dimensional digital elevation model, ignoring the three-dimensional target on the ground. The top is corrected and does not coincide with the bottom, resulting in a projection difference in the corrected orthophoto [9]. In recent years, with the development of photogrammetry and the improvement of the ground resolution of aerial imagery, traditional orthophotos will no longer be suitable for large-scale mapping, especially in densely populated urban areas, where dense tall buildings deviate from their correct positions. The occlusion and glancing phenomenon on the ground is very serious, which affects the application of traditional orthophotos [10], so "true orthophotos" has caused widespread concern. The true orthophoto is an upgraded product of orthophotos, which eliminates tilt error and projection difference. The true orthophoto is extremely strict with the original image [11], the heading overlap and side overlap are at least 80% and 60% and at least 3° overlap, in principle, requires a base ratio (B/H) of less than 0.3. The true orthophoto production is roughly divided into the following three points: (1) high-resolution data acquisition, DSM and DBM; (2) detection and identification of
occlusions and shadows appearing in repeated mapping; (3) for image defect areas repairs eliminate edge effects and more. The core difficulty is the detection and identification of the repeated mapping area, followed by the image masking area and the shadow area image restoration. The difference from the traditional orthophoto is that DSM replaces the DEM in the traditional orthophoto correction when digital differential correction is performed. The perspective distortion caused by the terrain fluctuation and the height difference between the ground object and the earth surface are corrected [12]. Differential correction using DEM will produce projection difference and perspective distortion, while differential correction using DSM will cause repeated mapping in the occlusion area of the object. Many experts and scholars at home and abroad have done a lot of research on the problem of repeated mapping (i.e., shadowing and shadowing) in the process of true orthophotos. Among them, Amhar[13] first proposed a Z-Buffer algorithm based on vector model to detect the masking area. Corrected separately based on DBM and DTM, and then combined the corrected two images to obtain true shot images, which were optimized by subsequent researchers [12,14-15]; Habit [16-17] proposed an angle-based occlusion detection algorithm. In the same projection direction, the projection ray angle of the occlusion area is smaller than the projection ray angle of the occlusion source; Bang[10-11, 15, 18-20] et al. based on the height-based occlusion detection algorithm, the algorithm compares the height of the ground point on the search path with the ray height for occlusion detection; Zhong et al.[15,21-26] used the characteristics of the interior polygons of the building to avoid each other, and propose a polygon-based inverse shadow detection method for imaging; Wang et al.[2,27] proposed aerial image shadow information enhancement method and image defect compensation information compensation method based on texture matching. Hu et al. [27-30] proposed an object-oriented occlusion compensation algorithm. Based on the above analysis, the image detection process is mainly based on Z-Buffer, angle, height, vector polygon, texture synthesis, object-oriented and other algorithms for mask detection and compensation. Each method has its own characteristics and scope of use. However, there is no comprehensive discussion on the algorithm of the true orthophoto. This paper focuses on the detection of the shadow area and the shadow area comprehensively analysis the relevant algorithms in the true orthophoto correction process, and points out the core of the current true image production problems and proposed solutions.

2. Image true orthophoto rectification algorithm

2.1.Z-Buffer algorithm
Basic principle [13], as shown in figure 1: the point of the feature on the same photographic light, there is only one ground point closest to the center of the photography is not blocked, and the rest are occluded. The occlusion situation is determined by calculating the distance from each point on the photographic light to the center of the photograph. Firstly, based on DBM and DTM, respectively, the correction is performed separately, and then the corrected two images are combined to obtain a true orthophoto; the advantage is that the algorithm is simple and easy to implement; insufficient: the DSM accuracy requirement is relatively high, if the DSM data model used is resolution and original if the image resolution is inconsistent, pseudo occlusion and pseudo-visibility will occur. For the long and narrow vertical structure, the M-Portion problem will occur [31]. By dividing the image into four for true orthophoto correction, the most Z-Buffer algorithm is optimized, only Increased computing speed; Rau[32] et al. proposed a Z-buffer algorithm based on the grid model, which detects the edge points of the wall of the building, then divides the wall into several parts according to the height of the building, and finally performs the wall points. Shadow detection. Advantages: The problem of ghosting in the building wall obscuring the ground object is solved; insufficient: the calculation amount is large, and the image processing efficiency is lowered. This method solves the problem of tree occlusion in forest areas. Xie et al. [22] proposed a blind detection method based on the minimum boundary sector (MBS) of digital building model (DBM), which improved the detection efficiency, but there may still be problems such as false shadowing and pseudo-visibility. Hua [33] proposed a true orthophoto occlusion detection algorithm combining SGM and Z-Buffer can solve the pseudo-visible problem. Li [34] and

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others extracted houses from DSM in high-density residential areas, and proposed a morphological filtering algorithm based on continuous-scale detection. The algorithm has high correctness and accuracy. The disadvantage is that for sparse small houses may be missed, for the M-Portion problem, this algorithm can be used for detection.

2.2. Angle-based shadow detection algorithm
The basic principle [16], as shown in figure 2: in the same direction of the projection direction, based on the ground point, the angle between the photographic light and the plumb line is proportional to the distance from the ground point to the photographic point; when the occlusion area is encountered, the elevation value due to the occlusion will be smaller, causing the angle to become smaller, and until the visible area, the projection angle is restored again. The occlusion is judged by comparing the change in the angle between the photographic light and the plumb line. Sheng et al. [17] proposed an angle-based multi-view synthesis strategy, which is mainly applicable to forest areas. Wang [19] used the scanning method of angle detection method and the idea of ray tracing method to optimize the moving elevation algorithm, which significantly shortened the running time, complete the detailed detection, and the edge information detection was smoother and more accurate. Advantages: make up for the deficiency of Z-Buffer, there will be no false occlusion and pseudo-visible phenomenon; Disadvantages: the calculation process is complicated, the calculation amount is large, and the efficiency is low.

2.3. Height-based shadow detection algorithm
Basic principle [16], as shown in figure 3: Buildings with high elevations block low elevations and are not likely to have high elevations to block tall buildings. The algorithm compares the height of the ground points on the search path with the height of the rays for shadow detection [11]; Zhang [10] proposed a DSM-based occlusion detection algorithm, which divides the DSM into multiple blocks centered on the ground point, and performs mask detection based on the DSM after block sorting, and performs GPU-based detection. Parallel acceleration implementation. Advantages: reduced complexity after block and high efficiency. Wang [14] proposed a ground-based radiation distance shadow detection algorithm, and the ground objects close to the ground point block the ground objects far from the ground. The idea of determining the shadow relationship based on the distance is also determined by scanning.
from the bottom point. Advantages: improve the execution efficiency and accuracy of the algorithm. Yang [18] solved the problem of compensation for other information occlusion of tall buildings by data preparation, real position calculation of buildings, calculation of occlusion area and filling and compensation of occlusion areas; Oliveira et al. proposed a data based on lidar data. The height gradient occlusion detection method solves the problem of repeated occlusion, but the visual analysis is not effective.

Figure 3. Angle-based shadow detection algorithm [14]

2.4 Shadow Detection Algorithm Based on Vector Polygon Inversion Imaging
Principle method: Kuzmin et al. [24] detect the masked area according to the intersection of the square polygons, and project the square polygon of the building to the image side to obtain the image polygon. When the number of buildings in the urban area is dense, the intersection of the object square polygons the state takes more time. Zhong [21] proposed the mask detection method based on polygon inversion imaging by using the characteristics of the interior polygons of the building without mutual obscuration, and the shadowing relationship between the targets and polygons during image inversion imaging; Sheng [23] The polygon is the basic unit. By comparing the angle of view, the building is back-projected into the image space by projection transformation, which is used to invert the target state during imaging, and obtain the shielding relationship between the polygon and the target. Zhong [25] proposed a vector-based backward projection (VBP) method for detecting occlusion. The advantage is that the false occlusion and pseudo-visible phenomenon caused by factors such as resolution difference are effectively avoided, and the disadvantage is that the vectorization workload is large and the calculation is complicated.

2.5 based texture matching algorithm
Compensation method for image defect information: Wang[2] proposed aerial image shadow information enhancement method and image defect information compensation method based on global variational model and texture matching, which further enhanced the interpretation ability and aesthetic effect of the image; Li[35] A fusion algorithm based on pulse coupled neural network model (PCNN) is proposed. Because the PCNN model conforms to the characteristics of human eye, it is introduced into the image of remote sensing image, and the obtained fusion image has smaller spectral distortion and better spatial texture details. Wang [36] proposed to eliminate edge aliasing effect based on line segment matching and further optimize image compensation. The algorithm requires a high texture structure of the image, otherwise it will affect the visual effect.

2.6 object-oriented occlusion compensation algorithm
Zhou et al. [27] proposed a new method for detecting occlusion of building visual walls. By establishing a model to describe the relationship between ghost images and occlusion, and then applying seed growth method to detect ghosts according to the boundaries of buildings. The occlusion area on the image; Hu [28] proposed a segmentation-oriented occlusion compensation algorithm, which does not require cumbersome quality evaluation for each pixel, and only needs to estimate the cost of each segment. Zhu [37] proposed object-oriented true shot correction method, which can maintain the accuracy of geometric features and the integrity of texture structure and the good visual effect; Angelo[30, 38]
proposed a high performance the triangle mesh generation method is used for mesh reconstruction, but the repair aspect needs to be improved. Bian [39] proposed a method for texture synthesis based on effective pixels by improving the Criminisi algorithm. This method compensates the masked region by introducing a DBM model and a sample-based texture synthesis method. It can solve the problems of duplicate mapping well and provide a reference for image restoration problems.

3. Conclusion and prospect
This paper summarizes the image true orthophoto correction algorithm, and points out the difficult problems of image detection and shadow compensation in image production, and finds that the existing algorithms are mainly divided into six categories, which are based on Z-Buffer and angle-based. Height-based, vector-based polygons, texture-based synthesis, and object-oriented algorithms. In summary, the algorithm solves the problem of mask detection and shadow compensation, but there are the following problems for a single algorithm: (1) large computation and complicated process, occupying computer memory; (2) pseudo occlusion and pseudo-visible phenomenon; (3) The accuracy of the data model is high; (4) The scope of the algorithm has limitations, and is only applicable to urban areas or forests. In view of the insufficiency of the algorithm, this paper proposes that for the urban buildings and other dense areas, continuous-scale morphological filtering algorithm can be adopted for building identification; when based on texture matching for occlusion compensation, the PCNN model method can be used first to enhance the texture features. Then, the mask detection and identification are performed; for the image defect area, deep learning can be considered to further repair, and the feasibility of the algorithm is enhanced and the calculation time is reduced, so as to optimize the true orthophoto rectification algorithm.

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