Study on the application of point cloud denoising in Gobi desert surface

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Abstract. Affected by the noise of desert environment and UAV mechanical system, the surface point cloud data will be mixed with noise points when we extracted the data from photos of UAV with overlapping regions. These noise points will seriously reduce the precision of DEM and DLG. In this paper, we use a denoising combination of two filter methods, Topscan filter is used to remove large-scale noise points and bilateral filter is used to deal with small noise during the surface point cloud. Experiments shows, the denoising combination can remove the noise points and improve the quality of aerophotogrammetry products.

1.Introduction

In recent years, UAV (Unmanned Aerial Vehicle) aerophotogrammetry technology has developed rapidly under the strong push of social demand. It is an important supplement to traditional measurement techniques[1]. UAV aerophotogrammetry gives up the inefficient manual mapping mode and calculates the surface point cloud through the aerial triangulation algorithm and interpolate to generate DEM (Digital Line Graphic) and DLG (Digital Line Graphic). UAV aerophotogrammetry has many advantages: flexible, low cost, wide application, fast and efficient. In small area and difficult areas of traditional mapping, UAV aerophotogrammetry can get large scale digital products quickly and works well. But, data processing of aerophotogrammetry has many limitations in Gobi desert. In the Gobi desert, vast in territory, sparsely populated and plant with the complicated topography conditions, the field survey and mapping is difficult and inefficient in this area. At the same time, the wind sand are strong in spring, the colors of surface and plant are small contrast in winter. Affected by above desert environments and UAV mechanical system, the surface point cloud data will be mixed with noise points when we extracted the data from photos of UAV with overlapping regions[2]. These noise points will seriously reduce the precision of DEM and DLG.

In order to improve the accuracy of point cloud, many scholars have made contributions to this work, Song improved C-means algorithm to remove the large-scale noise for solving the 3D point cloud data noise and outliers[3]; Wang present a new denoising algorithm for scattered point clouds. The algorithm first establishes the spatial topology relation of point cloud by the improved K-means clustering algorithm. Then it recognises and removes the noise points on every kind of clustered point cloud[4]; Zhu present a novel hierarchical outlier detection method which is proposed for the automatic outlier detection of point cloud from image matching[5]; Fleishman applying bilateral filtering in image processing to 3D point clouds, but it will ignore local features when dealing with large range noise[6]. However, the effect of applying single denoising methods in engineering application is poor. Consequently, it is necessary to study the filtering method suit for desert

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topography in Gobi desert, the purpose is to remove the noise points from the point cloud, and improve quality of aerophotogrammetry products.

2.Noise classification

By analyzing the causes of noise in Gobi desert surface point cloud, we know the redundant noise is divided into two categories, one is called large-scale noise, the points above the surface point cloud; the other is small noise during the point cloud called small-scale noise. We will classify and deal with them.

It was found in the project, the large-scale noise points including the sparse points above the cloud, the numbers of sparse points will increase significantly when the wind sand is strong; on the other hand, some points cloud is far away from the main cloud, small and dense, with high frequency and large value, the main cause is the high vegetation. The large-scale noise points can be removed by using Topscan filter.

There are some small-scale noise points during the surface point cloud after removed large-scale noise points. This kind of noise will disturb the smoothness of the point cloud and make the surface undulating and distorting. It was found in project, the reason is low vegetation cover, just like camel thorn. This plant is very common in Gobi desert, it will increase the probability of mistaking camel thorn as a ground in the aerial triangulation, and reduce precision of products finally. These noise can be removed by using bilateral filter. The bilateral filter can not only retain the characteristics, but also remove the small-scale noise points.

3.Figures and tables

3.1 Topscan filter

Topscan was first used in laser radar scanning, the idea of Topscan filter is to divide the processed point cloud data into virtual grids firstly, and find the lowest point out from every grid through calculation, the set of the lowest points is used as ground point set; Secondly, fitting the altitude of the point with adjacent grids, if the difference between actual altitude and fitting altitude of the point is greater than threshold, it shows that the points are not on the ground and we should remove them; Finally, we reduce the size of the virtual grid, repeat the iteration according to the above method. In this way, we can filter out the no ground noise points from the point cloud. In the Gobi desert project, Topscan filter can be used to deal with the large-scale noise, like wind sand and high vegetation.

3.2 Bilateral filter

Bilateral filter[6] is an image processing method, it can not only retain the characteristics，but also remove noise points. Because of the similarity between point cloud data and digital images, bilateral filtering can be used to solve point cloud denoising.

Both bilateral filter and Gauss filter realize data denoising and smoothing by means of weighted average of adjacent points. But, compared with Gauss filter, bilateral filter increases the filtering function based on spatial distribution, and considers location and space information at the same time. However, bilateral filter also has shortcoming, the filtering effect is not satisfactory for the regions with large-scale noise. It is necessary to carry out typical anomalies before filtering points by bilateral filter. The Topscan filter can be used to remove the typical anomalies.

The idea of bilateral filtering is to determine a tangent plane close to the data model and move the vertex to the tangent plane position along the normal direction. The equation is shown as follows:

$$\hat{v} = v + d \times n \tag{1}$$

In the equations 1, n is normal vector; $\hat{v}$ is the denosing data; v is the initial data; d is the bilateral filtering factor, shown as follows:

$$d = \frac{\sum_{q \in s} G_{\sigma_s}(\|p-q\|) G_{\sigma_r}(\langle n, p-q \rangle) \langle n, p-q \rangle}{\sum_{q \in s} G_{\sigma_d}(\|p-q\|) G_{\sigma_r}(\langle n, p-q \rangle)} \quad (2)$$

In the equations 2, s is the set of adjacent points, q is the point in s, σ_s and σ_r is Gauss factor. $\|p-q\|$ is the geometric distance between p and q, $\langle n, p-q \rangle$ is the vector inner product of n and p-q, G_{σ_r} is weight value of distance, G_{σ_r} is weight value of local normal vector difference, shown as follows:

$$G_{\sigma_s}(x) = \exp(-\frac{x^2}{2\sigma_s^2}) \quad (3)$$

$$G_{\sigma_r}(x) = \exp(-\frac{x^2}{2\sigma_r^2}) \quad (4)$$

4.Experiment and analysis

We implemented the Topscan filter and bilateral filter by programming in the Matlab and set the grid and the threshold according the actual situation. Applying our program, the filter effect of the local point cloud is shown in Figure 1-2. Figure 1 shows original point cloud data，the data contains concentrated noise called typical anomalies. Figure 2 shows the data after Topscan filtering, experiments shows the altitude of test area decreased from 0.9m to 0.42m, elevated vegetation noise is removed.

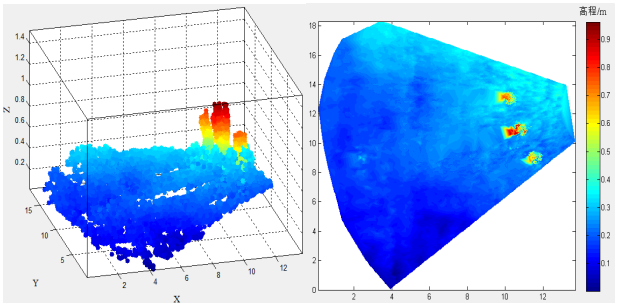


Fig. 1. Point cloud without filtering.

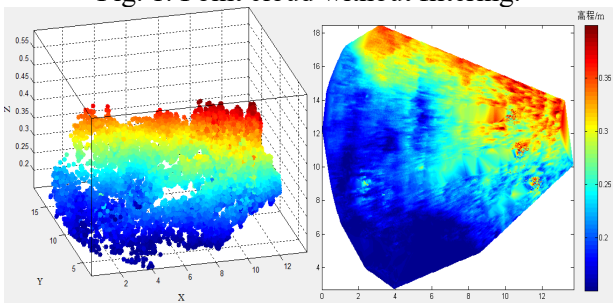


Fig. 2. Point cloud after Topscan filtering.

After Topscan filtering, the large-scale noise in data is removed, we further deal with the small noise by bilateral filter. Experiments shows the altitude of test area decreased from 0.42m to 0.38m, as shown in Figure 3，the noise caused by low vegetation is removed mostly, and the ground retain the characteristics at the same time.

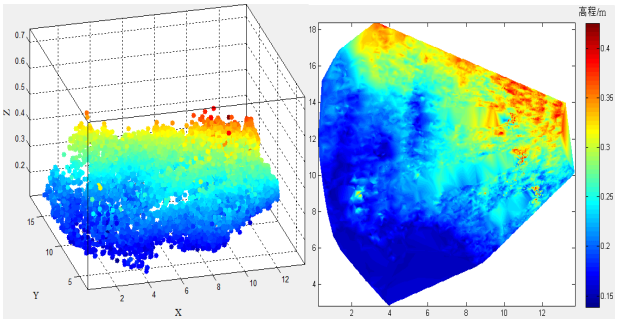
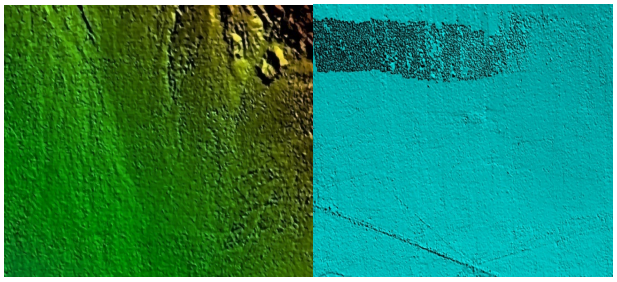


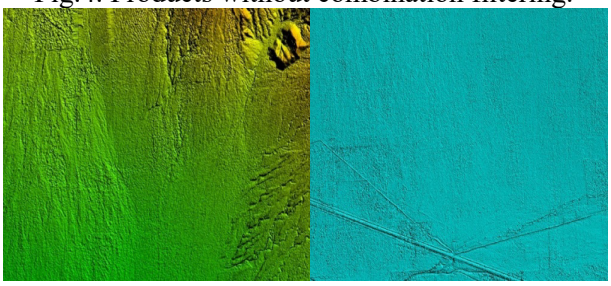
Fig.3. Point cloud after bilateral filtering.

The combination of Topscan filter and bilateral filter is applied to the project of UAV aerophotogrammetry, Figure 4 is the Products without combination filtering, there are many noise points even noise band in the image. After combination filtering, the numbers of noise reduced significantly.

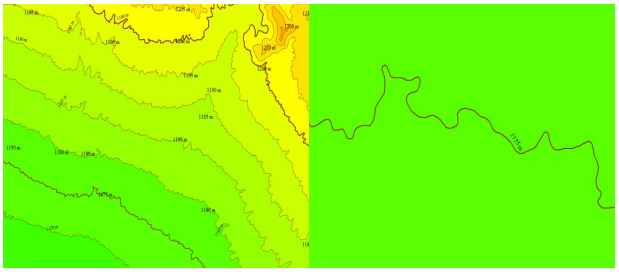


（a）DEM （b）Terrain profile

Fig.4. Products without combination filtering.



（a）DEM （b）Terrain profile



（c）Contours(local) （d）Contours(detail)

Fig.5. Products after combination filtering.

Experiments shows the combination of Topscan filter and bilateral filter is suitable for denoising point cloud of UAV aerophotogrammetry is shown as Figure 5; a is DEM, we can see that the small-scale noise is significantly reduced, and the product is close to real; b is the Terrain profile, it shows that the large-scale noise band is removed compared with Figure 4 b, terrain profile is smooth; c and d are the contours, produced by DEM, and the curve is smooth. In a word, the products of DEM and

DLG after combination filtering is better than using a single method to deal with, local noise is significantly reduced, the terrain does not fluctuate, and there are no noise points.

5.Conclusion

UAV aerophotogrammetry technology is an important supplement to traditional measurement techniques. It has many advantages in small area and difficult areas of traditional mapping. However, affected by above desert environment and UAV mechanical system, the surface point cloud data will be mixed with noise points when we extracted the data from photos of UAV with overlapping regions. These noise points will seriously reduce the precision of DEM and DLG. We propose a denoising combination of Topscan filter and bilateral filter to remove the noise from the Gobi desert surface point cloud in the project. Experiment shows the denoising combination can remove the noise points from the in point cloud and improve quality of aerophotogrammetry products.

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