ELEVATION EXTRACTION AND OBJECT RECOGNITION FROM AERIAL STEREO IMAGES

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1. INTRODUCTION

Stereo image matching is to find conjugate points on overlapping images pair, i.e., search for the same image pixels of a ground point on the left and right images. When the image orientation parameters are known, the 3D (X,Y,Z) coordinates of the ground point can be calculated. This process is the core part of DEM (Digital Elevation Model) generation in digital photogrammetry. Research on this topic was very intensive in the past decades, and many different methods have been proposed. But, this problem is still not completely solved. The difficulty comes from many sources, such as radiometric distortion, geometric distortion, occlusion, repetitive pattern and lack of features, etc. [1]. The matching result usually has lots of mis-matches, especially along the boundaries of the ground objects, like road and house. In this paper, a method to use areas, multi-scale regions, recognized objects as matching entities is proposed. This method can dramatically reduce the mis-match, and generate more meaningful matching result.

The presented research scheme includes the following key steps:

(1). Multi-scale image segmentation

(2). Object recognition/Classification

(3). Matching using areas, multi-scale regions, and recognized objects

(4). Bare earth surface reduction

(5). Manual editing of the automated matching result

The post processing steps (4) and (5) are needed to get the bare earth DEM, as the result of the automated stereo matching process is a DSM (Digital Surface Model).

2. METHODOLOGY

2.1. Multi-scale Image Segmentation

The multi-scale segmentation algorithm by Baatz [2] is used. In this algorithm, the image is segmented at different scales. Each scale represents objects at different abstraction levels. Higher level region contains lower level regions. At higher level, a region might represent a forest; at lower level, a region might be a single tree in the forest.

2.2. Object Recognition/Classification

With the multi-scale segmentation result, some objects, like buildings, roads and vegetation areas are recognized or classified. The recognized objects are matched and the matching results are used for refine the object recognition as explained in the following paragraphs. These object recognition and matching are executed alternatively to improve the performances of each other.

The strategies to recognize/classify the buildings, roads and vegetation are implemented and summarized below. A homogeneous region is considered as a road if it is elongated with smooth parallel boundaries and has almost consistent width along the running direction. After the matching result is obtained, the road can also be verified by checking whether the matched points form a smooth 3D surface. Buildings are detected as homogeneous regions with pairs of almost parallel boundaries, and some of the pairs are almost perpendicular to each other. Buildings are also above the surrounding ground and have limited height ranges. The 2D building detection need not be perfect, only the building outline or part of the outline, or even just some cue of the buildings existence is useful. The matching result is used to help detect the full extent of the building by fitting points to 3D planes. Vegetations are identified by irregular region boundaries and texture analysis. If color or infra-red images are available, the color or NDVI can also be used. Additionally, the matched point elevations have high variance over the vegetated areas.

2.2. Matching

The matching is performed on epipolar images. The epipolar images can be created before or after segmentation and object recognition. The multi-scale region, recognized objects are used for matching. First, the larger and more prominent recognized objects are matched, then the smaller ones. The higher level regions are then matched and followed by regions at lower levels which are inside larger regions to get denser matches. To search for conjugate objects, the objects' types, areas, perimeters, orientations, etc. are compared; for regions, similar properties are used for comparison. Only those matches with a high confidence are kept. During the matching process, dynamic programming is used to get an optimal solution [3]. The recognized objects are matched first because they are more unique and easier to match, so should be more reliable. Utilizing this strategy, the match is more reliable and efficient. Properties of objects, like "road surface is smooth and building roof is planar" are used as constraints in the matching process.

2.3. Bare Earth Surface Reduction

The matching result is a DSM (Digital Surface Model), i.e., elevations of the tops of objects. In photogrammetric applications, the DEM representing the bare ground is the desired product. So, the DSM must be reduced to a DEM. Filtering is the approach most researchers have used to produce a DSM from a DEM. The problem with filtering is that they are based on some models which are not necessarily correct. In addition, they are done blindly, without knowing what is on the ground, let alone the properties of the objects on the ground. This will result in smooth surface with important details smoothed out. Object oriented surface reduction discussed in this paper can overcome some of the problems. The object oriented approach can utilizes the object characters to facilitate the surface reduction.

Road surface is expected to extract correctly during match if the road segment was detected. It can be further refined by forcing points on the road to fit onto piecewise smooth surfaces. Building roof points can be deleted or reduced to bare ground easily if the outline was extracted correctly. The building occupied area can generally be treated as a flat plane. In the absence of good building extraction, (TIN) surfaces can be constructed around the building area; the points at higher plateaus can be considered as non-ground points and reduced. Another approach is to build a histogram of the points' elevations. A histogram with two dominant peaks is anticipated. Separate the peaks at the trough; elevations at the left of the division are considered as bare ground. For vegetated area, some matched ground points may be found; after fitting the on-ground points with a smooth surface, other non-ground points can be deleted or reduced.

2.4. Manual Editing of the Matching Result

After all the automated process, usually, there are still some mis-matched points, and need manual process. A manual stereo editing tool was developed and was applied to NCRST (National Consortium on Remote Sensing in Transportation) [4] [5] and WBI (Wisconsin Buffer Initial) projects. Some useful editing functions were implemented. Points to be edited can be selected, and then their elevations are adjusted by moving up/down or fitting to plane; the unwanted points can also be simply deleted.

3. EXPERIMENT AND CONCLUSION

The study area selected for this study is along Iowa State Highway I south of Solon, Iowa in Johnson County (Figure 1), between Cedar Rapids and Iowa City in eastern Iowa. The result proved the efficiency and high accuracy of the described method. The DEM generated with this method has better accuracy in terms of RMSE than other existing methods. The manual editing time of the matching results is significantly reduced.

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