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Object Segmentation in Elevation Space Using Mathematic Morphology

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Abstract

ABSTRACT: The original Digital Surface Model (DSM) produced from image matching in digital Photogrammetry or from scanning by Airborne Laser Scanner (ALS) are the mixing representation for ground, buildings, trees and many others. The ground surface and those objects above the ground may be segmented from the DSM. We propose two mathematic morphology methods, Top-Hat Transformation and H-Dome Transformation, to reconstruct DSM to separate those objects from the ground surface. The procedure of the proposed methods includes: (1)Top-Hat Transformation to filter out the noise in elevation space. (2)H-Dome Transformation to detect the local regional maxima as the objects above the ground. Experimental results indicate that the proposed method might reach high reliability. It is also found that those objects above the ground may further be used in building detection provided that other inputs are available, and DTM production.

1. INTRODUCTION

The original Digital Surface Model produced from image matching in digital Photogrammetry or from scanning by Airborne Laser Scanner are the mixing representation for ground, buildings, trees and many others. For many applications it needs further process to separate those data into ground surface and objects above the ground. For producing Digital Terrain Model (DTM), the photogrammetric operators sometimes tend to measure the limited amount terrain points manually. This paper proposes two mathematic morphology methods in elevation space to segment the objects above the ground. The proposed methods are fast and suitable for many terrain types. Experimental results indicate its high ability for building detection and DTM production.

2. LITERATURE REVIEW

Here we are going to introduce some algorithms about object segmentation in DSM.

Two algorithms to filter out the points of buildings or vegetation in a DSM derived from Airborne Laser Scanner (ALS) are presented below. First, the algorithm used by the Company TopScan is to move a rather large window on the DSM and to find a lowest point in it. A point is removed when its height difference exceeding a threshold. The step is repeated several times by reducing the window size and finally leading to the DTM. Because this algorithm couldn't eliminate object points without removing the points on structure lines, the parameters, i.e. window sizes and threshold, depend on the morphology of the terrain and have to be different for flat, hilly and mountainous regions [Petaold et al, 1999].

Another algorithm proposed by Kraus and Pfeifer [1998] is based on linear prediction with an individual accuracy for each measurement. It works iteratively and patch-wise. First it supposed a value below the averaging height in a patch containing points on the ground and the vegetation. This method introduced a robust estimation by selecting proper weight. For the supposed height being near the terrain, the residual of ground points will be smaller than those on vegetation. Thus, a larger weight is assigned according to the residuals. It proceeded by analyzing the histogram of the residuals of the previous iteration and reaches the expected standard deviation to the DTM.

The digital Photogrammetry workstation "SOCET SET" of LH systems provides a capability to filter out the artifacts above the ground [LH systems, 2001]. Before using the tool, one needs to input two parameters, i.e. width and height. The algorithm depends on a slope threshold defined by grid spacing of DSM and the height. First it searches the X profiles by looking for an up-slope that exceeds the slope threshold followed by a down-slope of 80% of the slope threshold within the range of the width. When such an artifact is discovered, all points within the range are flagged. The search is then repeated on the Y-profiles. Only points flagged in both directions are regarded as above ground objects and will be eliminated. The function is just suitable for relatively smooth and flat terrain.

3. TWO MATHEMATIC MORPHOLOGY METHODS

The proposed method assumes that the objects above the ground locate on the local higher regions in elevation space. On the other hand, the terrain points are on the lower regions. Under this assumption, the mathematic morphology methods are introduced to detect the objects as local maxima. First, the Top-Hat transformation with a Flat Structuring Element is used to filter out points bulging on the terrain. However, the detectable size of object depends on the element scale, which is not easy to be defined automatically. For this reason, we use it to filter out noise in the first stage. Then we introduce the H-Dome transformation to detect those objects such as buildings or trees above the ground.

3.1 TOP-HAT TRANSFORMATION

The Top-Hat transformation is one of the gray scale morphologic algorithms and is beneficial in finding pixel clusters that are light on a surrounding relatively dark background. It can be used to find neuronal cells in a tissue sample and to extract blood vessels from an image using an X-ray system and fluorescent dyes [Dougherty, 1992]. This operation is illustrated in Fig.1. The transformation processes original signal f with opening by flat structuring element g. Fig.2 indicates that the peaks are detected as a Top-Hat by subtracting an opened image form the original image.

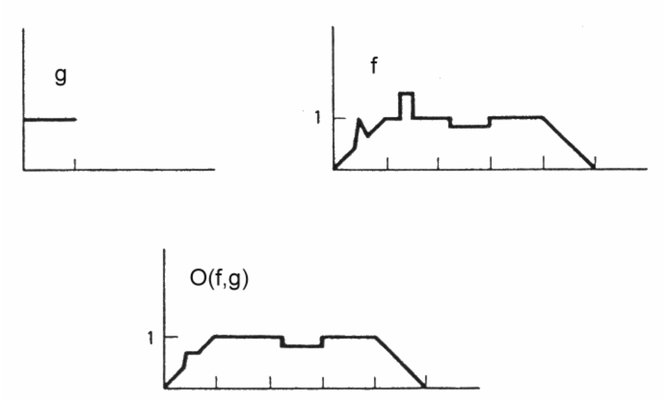


Fig1. Opening by flat structuring element [Dougherty, 1992]

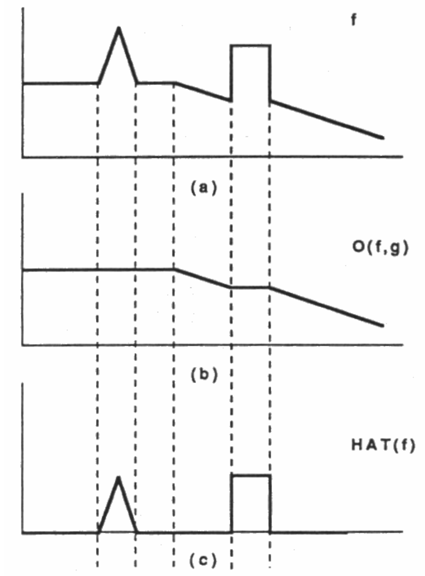


Fig2. Top-Hat Transformation [Dougherty,1992]

The opening operation includes two procedures, erosion and dilation. Because the structuring element is flat, the erosion is simplified to find the minimum gray level and the dilation to find the maximum during process. This operation seems to be able to detect the objects above the ground, but unfortunately the detectable size of object depends on the size of the element. Therefore we use this opening operation just to eliminate the peaks, like noise in elevation space.

3.2 H-DOME TRANSFORMATION

The H-Dome transformation was first provided in [Vincent, 1993] and was applied to detect the micro-aneurysms in an angiography of eye blood vessels, the cells of the corneal endothelial tissue of the eye, the spots of electrophoresis gel and so on. The H-Dome transformation is illustrated on fig.3. It defines the original image as mask I and the operator as marker image I-h. In this operation, every pixel on marker I-h has to be pulled up to the same height of its neighbor on the marker I-h and must be limited to its height on the mask I. Finally we can get a reconstrutive image. The image of h-domes comes from subtracting the reconstructive image form the original one. We notice that if the object points are higher than their neighbor, it will be easier to define the parameter h for detecting objects. But in addition to object points above the ground, some points on structure line like ridges may be also eliminate in this operation.

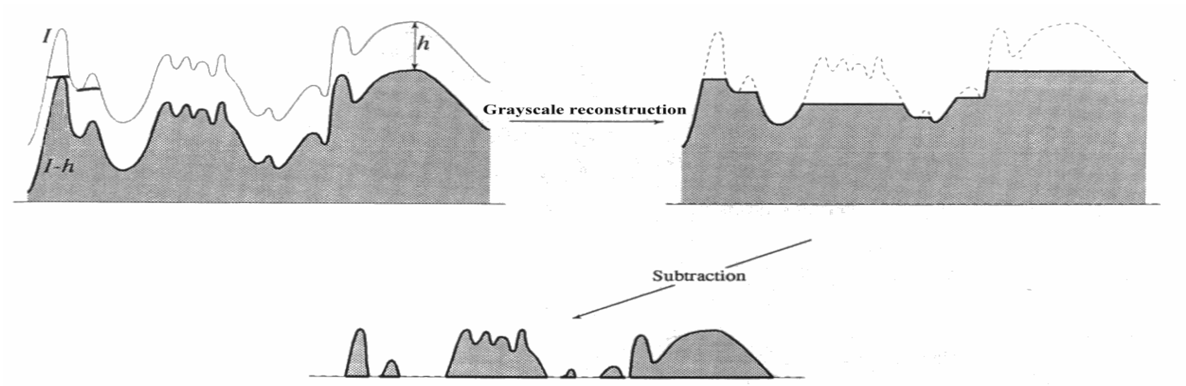


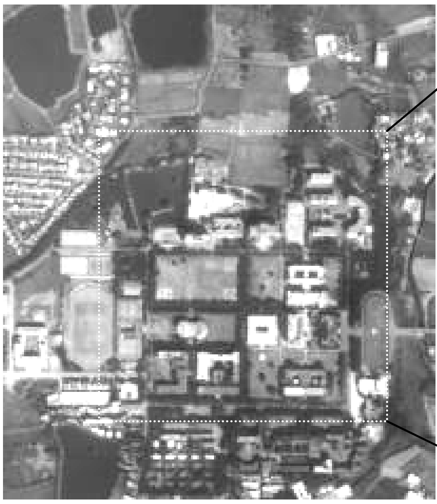
Fig3. Determination of the h-domes in grayscale image [Vincent, 1993]

During the processing, the height of each pixel will be changed by its neighbor, so it takes for many iterations to complete the reconstruction. A faster argorithm including sorting of pixels and queue for First-In-First-Out as proposed by Vincent [1993] improved the computation efficency significantly.

The advantage of the H-Dome transformation is scale-independent. It detects objects above the ground as local maxima and is thus suitable for many terrain types. Furthermore, this two mophological argorithms could be applied to DSM in grid model or TIN model.

4. EXPERIMENTAL RESULT

Fig.4 shows an aerial photo for the test area of 95*110 m^2 surrounding National Central University in Taiwan. Its pixel size is 12.5um and equals to the resolution 15cm on the ground. The DSM image showing in fig.6 is produced by using the tool of Automatic Terrain Extration (ATE) in the digital photogrammetry workstation SOCET SET. In this case, the DSM resolution is 2m, the flat structuring element is 5*5 and the h in H-Dome transfomatin is 30m. After the operation, fig.5 shows the overlay map of the contour of buildings and the segment image of h-domes which has sliced with 3m in height. This result indicates it could be used to detect the building location provided that other inputs like linear features or multi-spectrum image are available.



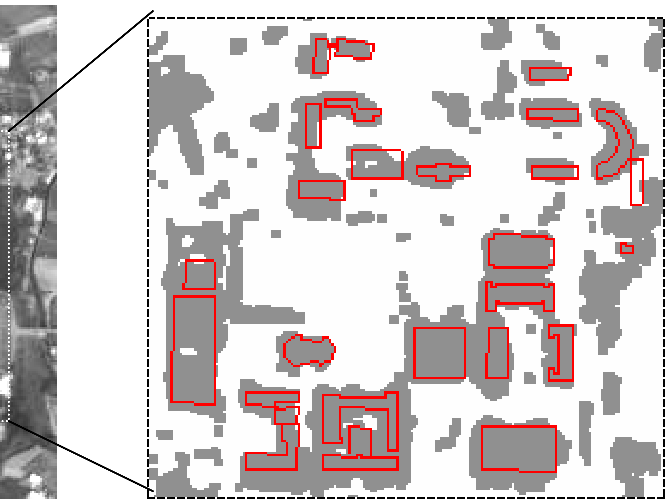


Fig.4 Case study area

Fig.5 h-domes with buildings contour

Furthermore, we use the proposal methods to filter out the object points above the ground and to produce DTM. Fig.7 shows the elevation points of 1458 after filtering out the points located on the areas of Top-Hat and H-Dome. In this case, the DSM is produced with a resolution of 10m, the flat structuring element in Top-Hat transformation is 9*9 and the h in H-Dome transformation is 4m. The generated contour map is illustrated in fig.8. Fig.9 is the contour map with 219 points measured by manual in the stereo model. We notice those terrains are very similar. While comparing those manual points with the ground points on the DSM from automatic collection, we found that the differental heights between the two terrains are around +1m. Those maximum and the minimum of differential height, +13.78m and –6.83m, locate on the ramp. By checking the two kinds of elevation points, we found that the manual points are a little lower than the height of its neighboring points in DSM. In addition, many points on ramp are filtered out because they are covered by buildings or vegetation.

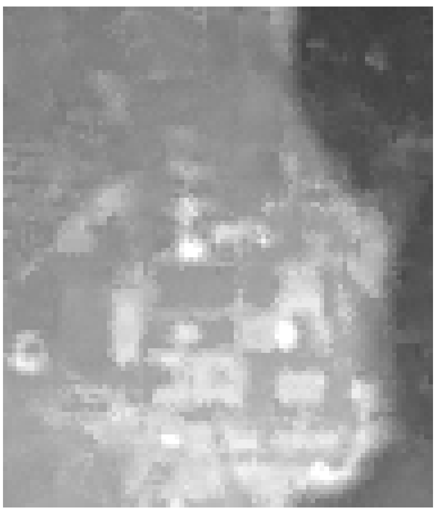


Fig.6 DSM image of study area

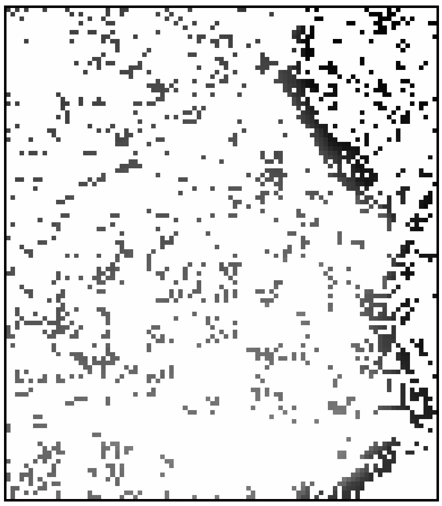


Fig.7 Elevation points after filtering

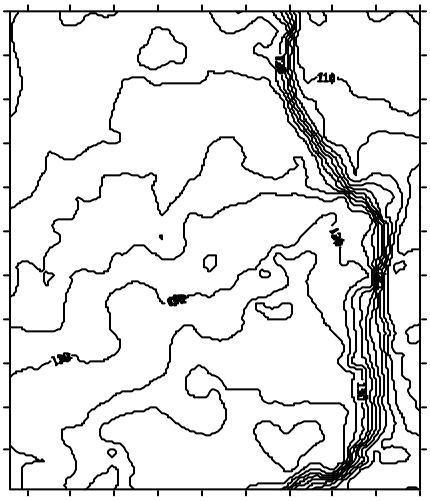


Fig.8 Contour from study methods

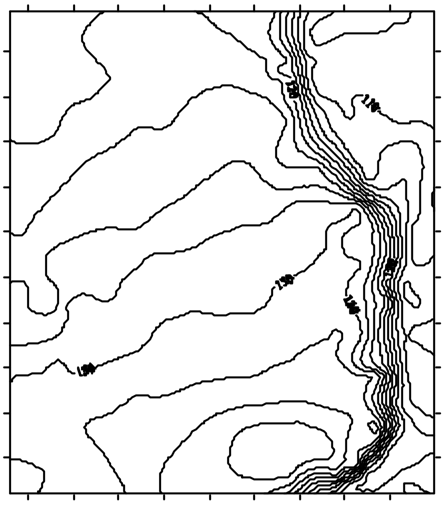


Fig.9 Contour from manual measurement

5. CONCLUSIONS

In this paper we propose a procedure to filter out the peak noise and to segment the objects as local maxima in elevation space. In such processing, the two mathematic morphology methods are suitable for object segmentation in a DSM. The algorithms could apply to different terrain types, even for DSM in grid data and TIN model. The mehtods could be used to detect buildings if other information like linear features or infred images are avaliable. For DTM procudction, the proposal methods can be used to filter out those points above the ground. Nevertheless, the manual check and some editions for structure lines from manual measurement are necessary.

6. REFERENCE

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