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AUTOMATIC EXTRACTING DEM FROM DSM WITH CONSECUTIVE MORPHOLOGICAL FILTERING

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ABSTRACT

Extracting DEM from DSM is a traditional and essential issue in photogrammetric research area. Recently, DSM is easily obtained by using LIDAR or UAV with dense 3D point cloud. DSM presents the earth surface including bare ground, tree, vegetation, building and other man-made objects. On the other hand, DEM presents bare ground, and do not include other features. Therefore, DEM is essential information for earth-volume calculation and urban planning in construction site. In this paper, we deals with automatic extraction of DEM from DSM with proposed consecutive morphological filtering method. Traditional extraction methods popularly used is minimum filtering, which is selecting lowest height in search window and determine it as the DEM height in interesting point. However, minimum filtering methods has a drawback in hill area and urban area. To overcome such defects, we propose the consecutive minimum and maximum filtering method. The experimental results shows the effectiveness of proposed method.

Keywords: *DSM, DEM, Morphological Filtering, Minimum Filtering, Maximum Filtering.*

I. INTRODUCTION

DSM(Digital Surface Model) represents all kind of man-made object and vegetation, tree, and bare ground. There are three famous digital models representing terrain. They are DEM, DTM, and DSM. Before making DSM, we need to differentiate these three models. The DEM (Digital Elevation Model) is a digital representation of the terrain surface, given by random data points with point clouds or raster grid data points with elevation given at regularly spaced point. The DTM (Digital Terrain Model) represents the topographical surface without vegetation or building. The DSM represents the terrain including vegetation and buildings. Maune (2001) introduced the differences between these three models. He said the DEM is a popular acronym used as a generic term for digital topographic data in all its various form, and the generic DEM normally implies x/y coordinates and z-value of the bare-earth terrain. In his book, DTM is synonymous with DEM representing the bare earth terrain with uniformly-spaced z-value, and DSM is similar with DEM or DTM except that it depicts the elevations of the top surfaces of buildings, trees, towers, and other features elevated above the bare earth.

DSM is easily obtained by using recent surveying technology. Traditionally, DSM is manually or automatically generated by using aerial imagery with GPS. However, the accuracy is not evenly distributed since the Z-axis accuracy for the aerial photogrammetry is lower than X-Y plane. The principle of LIDAR is calculating distance between antenna and object with the signal. Therefore, the Z- axis accuracy of LIDAR is similar with X-Y plane. LIDAR produces the 3D point cloud for the search area. These days, UAV(Unmanned Aerial Vehicle) is commonly used for surveying. The imagery obtained by UAV is simply process by using commercial software and it also easily produces 3D point cloud.

Extraction of DEM from DSM is a traditional and essential issue in photogrammetric area. DSM is used for true orthophoto, 3D city model etc. On the other hand, DEM is used for hydrology and bare-earth volume calculation in construction site or urban planning area. Since DSM is easily obtainable data in these days, easily DEM extraction algorithm from DSM is also an important issue. In this paper, we propose the technology which is easily separating non-ground point and ground point with consecutive morphological filtering method.

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II. DATASET

The DSM for this research was obtained from a LIDAR sensor. In recent years, LIDAR sensors have grown in popularity. A LIDAR is an active, range and direction sensing instrument capable of determining X, Y, Z (ground coordinates) of a very large number of points on the earth's surface. A LIDAR system consists of a laser scanner to transmit directed ranging pulses and detect the returns, a GPS/INS system to determine position and attitude, and a data storage device. A LIDAR system produces a cloud of irregularly spaced X, Y, Z and intensity points on the terrain. Since the LIDAR system produces X, Y, Z positions of points on the top surfaces of buildings, trees, towers, and other features elevated above the bare earth, we may call the result a DSM. According to Mikhail et al. (2001), current accuracies for LIDAR are about 15 cm in absolute elevation and about 5 cm in relative elevation.

In order to simplify the processing, we resample the irregularly spaced point cloud into a regular grid, a raster. In this DSM grid, elevations are stored in a regularly spaced grid, with horizontal positions referenced to any coordinate system, i.e. UTM or SPC (State Plane Coordinate). Practically, a grid (aligned with the reference coordinate system) is defined by an origin point, X and Y spacing, and the extent of the grid. Another common DSM format is the TIN (Triangulated Irregular Network), which uses an irregularly spaced set of points to approximate the object surface as a series of triangles. The advantage of the TIN approach is that, due to variable spacing, for a fixed number of points it can usually represent the terrain more accurately. Conversely for a fixed accuracy, the TIN approach can represent the surface with fewer points, compared with the grid approach. However determining the elevation of a point is more complicated than with the grid format. To interpolate an elevation for an arbitrary point, with the TIN you must search (slow), whereas with the grid you may directly index (fast). For the resampling of the DSM, the convention methods are nearest neighbor, bilinear, and bicubic. In order to best preserve edges we have used the nearest neighbor method. For the detail resampling method we used, refer the Youn and Kim (2008).

The DSM used in this research convers the Purdue Campus area in America. The original sampling density is about 1.8 points/ m^2. The determined sampling grid space is 0.5 meter. Figure 1 shows the DSM used in this paper.

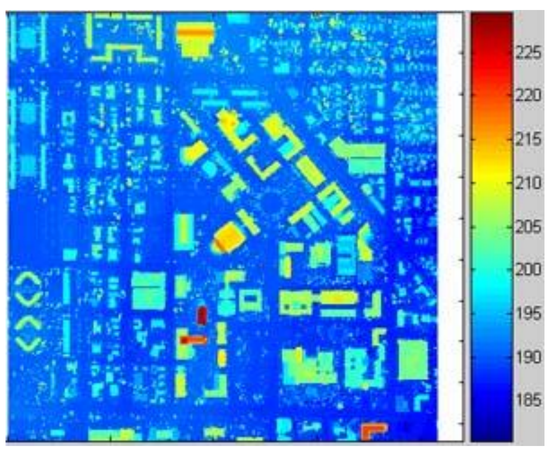

Figure 1. Used DSM

III. METHODOLOGY AND RESULTS

To separate the LIDAR points into ground and non-ground points, a morphology filter is a method commonly used by many research groups (Killian et al., 1996, Hug, 1997, Morgan and Tempfli, 2000, Morgan and Habib, 2002). In a morphology filter, one makes several search windows, and examines a highest value and a lowest value. Then the highest elevation value in the window represents the elevation of the top surface in the corresponding region and the lowest elevation corresponds to the bottom surface. We will assume that a ground point height is lower than its neighbor object points and the ground is reasonably horizontal (Ma, 2005). With these two assumptions, if one point's height is determined by a lowest height in neighboring points, then its height corresponds to the terrain height. Applying this process to the whole area, the composite of all such terrain points is similar to the DTM. We call it "close DTM". The process for making the "close DTM" is so called minimum filtering. Next,we calculate the differences between close DTM and the DSM obtained by LIDAR, then check the points whose differences are more than a threshold, and We can extract the buildings and trees. Therefore, making a "close DTM" as close as possible to the real DTM is a key issue for this approach.

However, such a morphology filter has several defects. One is that it is vulnerable to a hill (non-flat ground). It is also sensitive to window size selection and certain urban features to be described later. Because a height value for one point in a close DTM is determined by a lowest height in the predefined search window, the difference between a real DTM height and a close DTM height tends to increase when we use a larger size window. Also, this corruption appears when we apply this to a hill area. This is because the height difference between a point of interest and range of neighborhood points is small in a flat area, while the difference is larger in a hill area. Figure 1 shows an example of corruption of the close DTM in a hill area. In Figure 1, red dots denote the profile for an actual LIDAR height, and cyan dots represent the result of minimum filtering. Figure 1 shows there is a large corruption or discrepancy in hill areas compared to the small flat area on the right side of the figure. Large changes of height make the corruption for the close DTM.

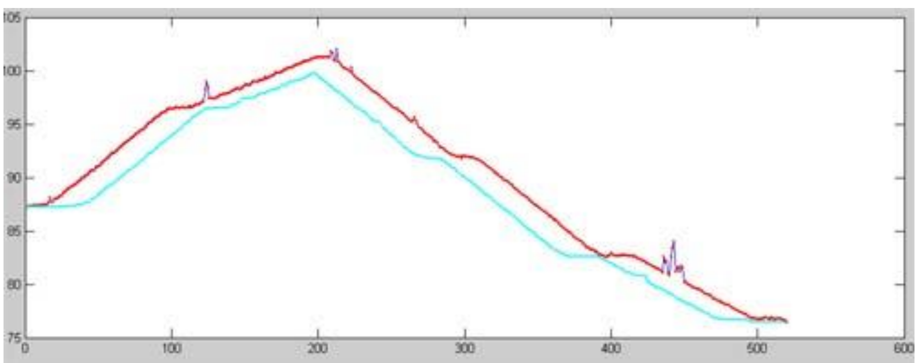

Figure 1. Minimum filtering over the hill area

We can see a similar problem in urban areas. Although the ground is flat, metal grates for utility access can exist in urban areas. Figure 2 shows the existence and effects of such metal grates around the buildings in the study area. The circles in Figure 2(a) represent the locations of metal grates. Figure 2(b), Figure 2(c), and Figure 2(c) are 3D visualizations of the study area. From Figure 2(b) above, it is hard to detect the existence of metal grates, while we can see the clear existence of metal grates in Figure 2(c) (view from below). Figure 2(d) is the result of minimum filtering with a 40meter size window. Because of these metal grates, there are significant corruptions of the close DTM as we can see in Figure 2(d). Since minimum filtering determines the height for one point in the close DTM as the lowest height in the search window, points less than 40 meters distance from the metal grate features are affected by its existence when we use a 40 meter size window.

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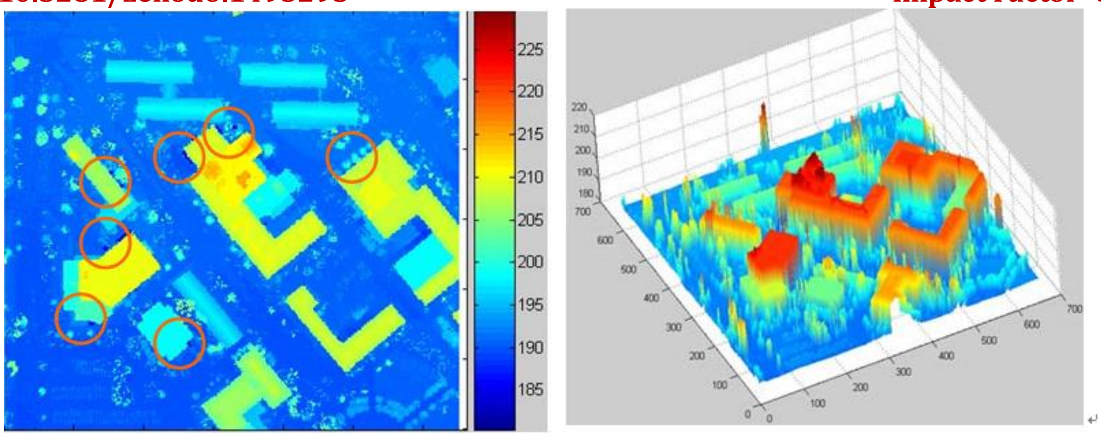
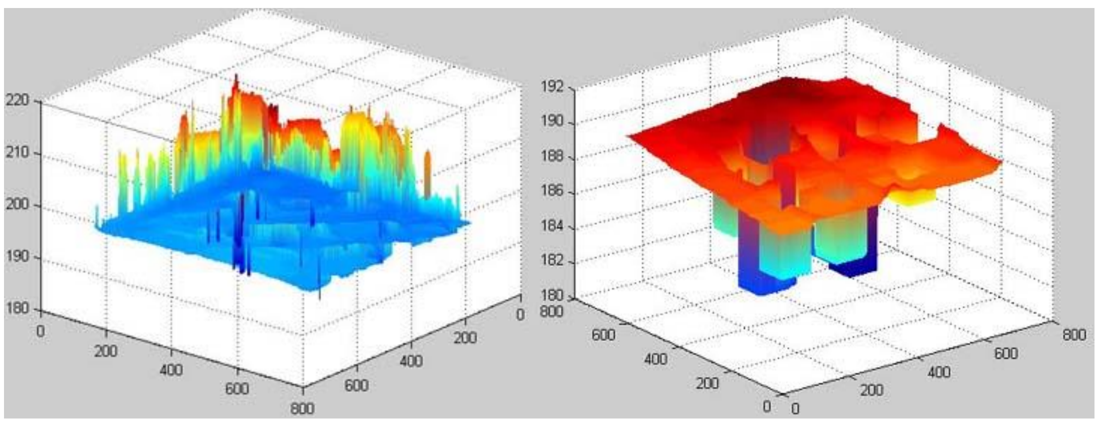


(a) (b)



(c) (d)

Figure 1Existence of metal grates and negative effects. (a) Height value in 2D (b) Seeing from upper side in (c) Seeing from lower side (d) Result of minimum filtering

To eliminate the effects caused by metal grates in urban areas, we propose the Maximum-Minimum filter. Maximum-Minimum filtering is a sequential application of maximum filtering and minimum filtering. Let us think again of the minimum filtering. Its ultimate effect is eliminating the higher objects. Seeing the height model in Figure 2(c) upside down, metal grates are just “higher objects” from the point view of the ground. Likewise we apply the minimum filter to eliminate effects of the higher objects, we can eliminate the effect of the lower objects by maximum filtering. Since the area of the metal grate is much smaller than a building area, we can use much smaller size of window for maximum filtering. Figure 3 provides the maximum filtering effects with the same area as in Figure 2. For this example, the search window used is 5 meter. Comparing Figure 2(a) and Figure 3(a), the overall building footprints are expanded due to the maximum filtering. However, as long as the distance between buildings is less than maximum filter window size, the buildings do not merge as result of maximum filtering.

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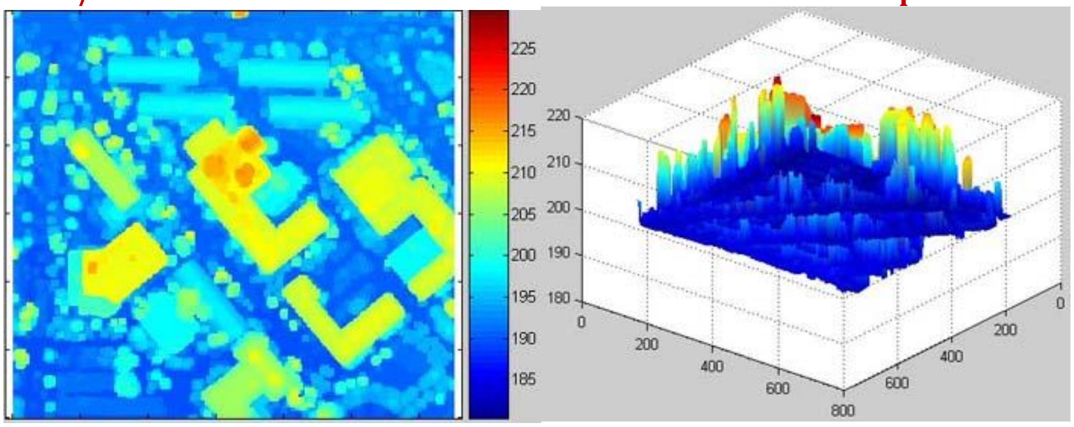

(a) (b)

Figure 2Maximum filtering with 5 meter size of window, (a) 2D view, and (b) 3D view

Also, sequentially applying minimum and maximum filtering produces more accurate close DTM in a hill area. Figure 4 shows the effects. In Figure 4, red dots denote the profile for the actual LIDAR height, cyan dots represent the result of minimum filtering, and blue dots denotes the result of maximum filtering after minimum filtering. In this experiment, we use the same window size for the minimum and maximum filter. With only minimum filtering, there is much corruption in the close DTM, but such corruption is drastically decreased when applying sequentially the two filters. So, the result of Figure 4 shows that a more accurate close DTM can be generated by sequentially applying the two filters in a hill area

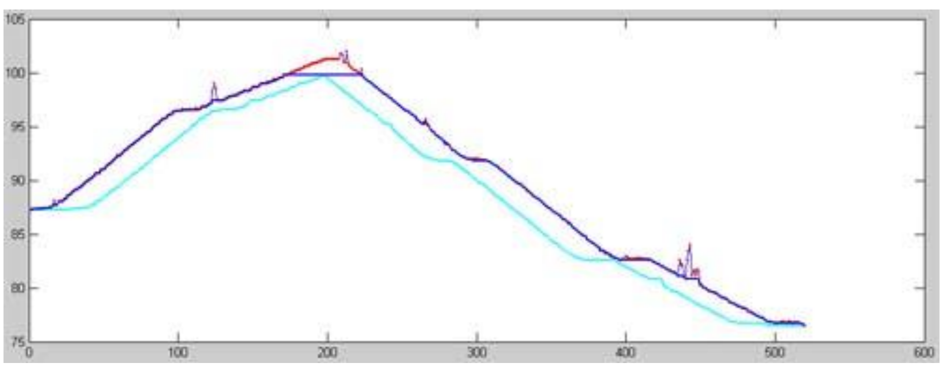

Figure 3Maximum filtering after Minimum filtering over the hill Area

As a first step for applying building extraction to the whole study area, we determine the window size. The size of window is determined as 150m × 150 m considering the largest building area for the minimum filter, and a 5m×5m window is used for maximum filtering. Second, we apply Maximum-Minimum filtering, and produce the close DTM. As a third step, the points whose DSM height is higher than the close DTM height by a threshold value are determined as above-ground objects in the building-tree (BT) map. If the difference between a DSM height and close DTM height is less than three meters, it can be a point for a tree, a car, or a human. Therefore we have provisionally chosen 3 m as the threshold. This third step can be expressed as

$$BT(i,j)=\begin{cases}1(\text{building or tree})\ if\ H_{DSM}(i,j)-H_{DTM}(i,j)\geq H_{th}\\ 0\,(\text{terrain point})\ otherwise\end{cases} \quad (7\text{-}1)$$

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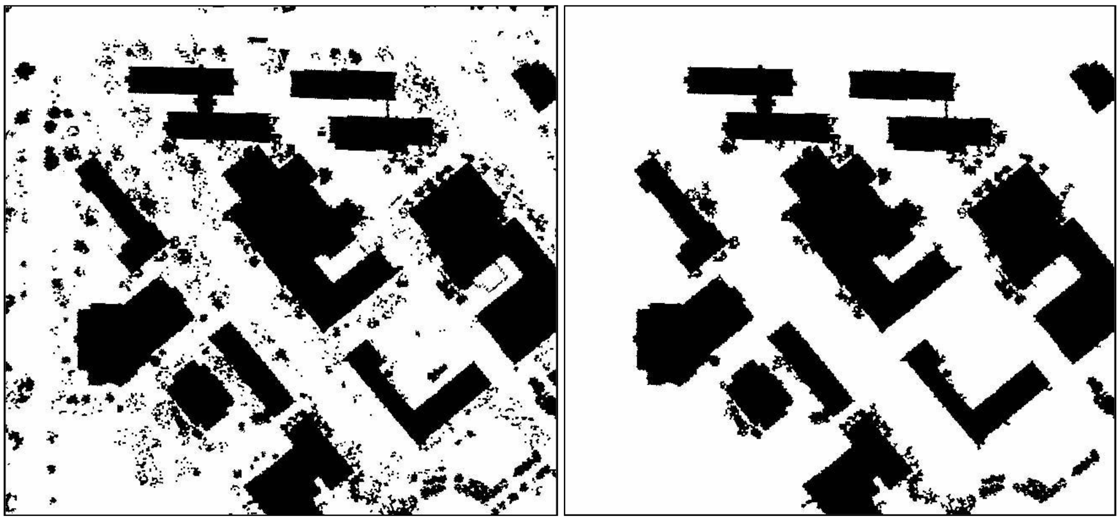
where $BT(i, j)$ denotes the value for the building-tree map corresponding to ith line and jth sample coordinate. $H_{DSM}(i, j)$ represents a height for DSM obtained by LIDAR, $H_{DTM}(i, j)$ represents a height for the close DTM made by the proposed algorithm, and H_{th} denotes the threshold height difference, i.e. three meter in this research.

With the first, second, and third steps, we detect the buildings and large size trees. As a final step, all components in the building-tree map are 8-connected labeled to determine the contiguous components. And the groups, with component numbers less than 400 pixel (corresponding to a 10m×10m area), are eliminated, since such small features are more like a car or very small building. Figure 5 shows the intermediate building extraction results. Figure 5(a) provides the building-tree map before eliminating small components, and Figure 5(b) presents the building map after eliminating. As we can see in Figure 5(b), trees are not completely eliminated. We need to exclude trees for complete building extraction.



(a) (b)

Figure 4Building extraction results (a) After filtering and comparing heights (b) After filtering, comparing height, and eliminating small regions

IV. CONCLUSIONS

In this paper, we propose the simple extracting DEM from DSM with consecutive morphological filtering. The proposed method is consecutive applying minimum filtering and maximum filtering to DSM. Minimum filtering is determining the height of interesting point with minimum height in x-y plane search window. Maximum filtering is determining the height of interesting point with maximum height in x-y plane search window. With minimum filtering, tree and building are eliminated, however, it distorts the DEM in hill area or metal grate spot in urban area. With consecutive applying those two filtering method, such distortion is minimized. Proposed method also has defect. It produces false DEM in top-hill area. For the further study, supplement technology should be developed.

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