

DEVELOPMENT OF AN INDIVIDUAL TREE CROWN DELINEATION METHOD USING LIDAR DATA

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ABSTRACT:

There is an increasing need for an accurate forest inventory for assessment of forest condition. Due to such a demand, an airborne LiDAR instruments have become increasingly popular in forest inventory. Tree detection and tree crown delineation from an airborne LiDAR has mostly focusing on utilizing the rasterized canopy height model. This paper presents a method for individual tree crown delineation based on triangulated irregular network (TIN) derived from point cloud. Tree crown borders were estimated by abrupt changes of surface normal vector calculated from the estimated tree top position. The vector-based approach was able to avoid trial and error such as a definition of mesh size or an interpolation method. The developed algorithm was tested in a park forest which includes various tree crown size. The results indicate that the developed algorithm was able to avoid the effect of holes in the tree crown area and was able to delineate the isolated tree crown regardless of tree crown size. However, it is necessary to improve the accuracy of estimation of tree top position and the decision method of search area

1. INTRODUCTION

Recently, cost-effective and sustainable mapping and monitoring methods are strongly needed for forest management. Remote sensing techniques are becoming a useful tool to help forest managers because they are able to obtain forest characteristics widely and uniformly. Light Detection And Ranging (LiDAR), one type of active remote sensor, is expected to support the development and application of site-specific analysis for forest management because small footprint airborne LiDAR depends on the estimation of characteristics of individual trees such as height, crown size and delineation.

Tree detection and crown delineation by LiDAR data has been studied. Tree tops have often been estimated by local maxima in the raster data after rasterization of point cloud, and crown delineation has often been undertaken by the inverse watershed algorithm (Koch, 2006, Mei, 2004). The watershed algorithm finds the boundaries of basins or watersheds, with Digital Surface Model (DSM).

In spite of LiDAR data being vector data, LiDAR data is handled as image data. Hence, it is deeply necessary to consider mesh size and an interpolation method in terms of rasterization of LiDAR data. Since LiDAR data consists of random points, the number of points depends on a specific mesh size. Even if point density is the same, when using large mesh size the detailed information of tree crown from the original point cloud has may decrease; on the other hand, when using small mesh size the true value at a specific pixel may change due to using a interpolation method such as nearest neighbour, interpolation with TIN and kriging method. Therefore, the accuracy of results derived from raster data depends on two variables: the rasterizing method and original point density.

Point density of LiDAR data will increase in the future due to technological innovation, so the point cloud on the surface of tree crown will be able to represent the detailed crown structure.

However, the issue of accuracy based on rasterization may still remain if a raster-based algorithm is applied to the future LiDAR data. If vector-based algorithm for crown delineation is developed, the accuracy depends only on the point density.

The objective of this study is to develop a vector-based algorithm for tree crown delineation.

2. DEVELOPMENT ENVIRONMENT

A desktop PC was used to develop the algorithm. The algorithm was coded using Matlab R2010a (The MathWorks, Inc.). Table 1 shows the development environment.

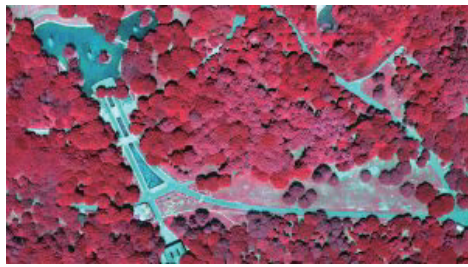
CPU	Core i7 920 (2.66GHz)
Memory	24GB
GPU	GeForce GTX 285 x2
Storage	2TB
OS	Windows 7 Professional 64bits
Programming language	Matlab R2010a

Table1. The development environment

3. STUDY AREA AND DATA

3.1 Study Area

The study area is located in Yoyogi Park in Tokyo. The algorithm was developed on a test area with side length of approximately 600 meters by 300 meters, which covers an area containing a mixture of tree types, road and a pond (see Figure 1). There are many isolated conical and broadleaf trees with large crowns along a road in the test area. Moreover, dense planting area is located at the centre of the test area. Figure 1 shows as overview of the test area acquired by a digital matrix camera from the air (top) and the view from the ground (bottom). The elevation of the test area is almost flat at 33 meters.



(Top)



(Bottom)

Figure 1. Overview of the test area acquired by an aerophotograph (R:G:B=IR:G:B) (top). View from the ground (bottom)

3.2 LiDAR Data

LiDAR data was acquired by ALS30 on 14 September 2004 while trees were in full on-leaf state. The LiDAR raw data consists of first- and last-pulse reflections with average point density 6 points/m². Due to the specification of the sensor, the points are irregularly spaced in a line pattern. In this study, all points were used to develop the algorithm.

4. METHODOLOGY

4.1 Tree Top position

Tree top position was estimated by the vector-based extraction method of tree top position (Endo, 2009). The algorithm is able to better extract the tree top position than the method which uses a local maximum filter method at dense planting trees with uniform shape. However, the algorithm overestimates several tree top positions on the surface of the large crown of broadleaf trees, since the algorithm is still in the development phase. However, the overestimation may be solved by a tree delineation method, and the tree top position data derived from this algorithm was applied to the LiDAR data in this study (See Figure 2). The estimated tree top position derived from the vector-based algorithm is shown in Figure 2.

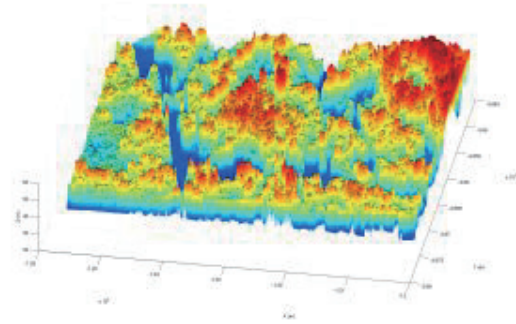


Figure 2. TIN image with the estimated tree top position at our test area.

4.2 Crown Delineation

The method for estimating tree crown delineation consists of four steps. The first step is the decision of search area, the second step is the extraction of points on surface of a tree crown area, the third step is the edge detection and the last step is the post-processing to overwrite initial values.

4.2.1 Search area

At first, a search area was defined in order to decrease computing time. Size of the search area was carried out the following steps:

- 1) The tree top with the lowest height value in the tree top position list was selected.
- 2) The distance between the selected tree top position and adjacent tree top position was calculated, and the shortest distance was defined as D_{min} .
- 3) A conical shape with a diameter of twice D_{min} on the selected tree top position was created, and the circumference of the bottom of the circular cone was defined as the search area.

The angle of tip of the conical shape (θ) depends on the largest bowl-shaped crown in a test area. In this study, the angle was set as 80 degrees due to the large size of the crown of the broadleaf trees in the test site.

4.2.2 Extraction of points on the surface of tree crown area

In general, laser beam hits not only the surface layer of the tree crown but also the inside of the crown. Therefore, the feature of the tree crown represented by point cloud is not smooth and several holes exist on the crown. The following procedures were conducted to avoid the effect of holes:

- 1) Triangulated irregular network (TIN) from LiDAR data was generated.
- 2) TIN inside the search area was selected. The selected TIN is defined as TINindividual in this study.
- 3) Surface normal vector of TINindividual was calculated.
- 4) The direction of the vector against the selected tree top position was confirmed and whether each vector was outer or inner vector against the tree top position was identified. Our hypothesis is that TINindividual with outer vector may be a part of the crown.

5) Only TINindividual with outer vector was extracted and the extracted TINindividual was defined as the surface of the tree crown area.

Figure 3 shows the conceptual diagram of the steps of the search area and the tree crown area.

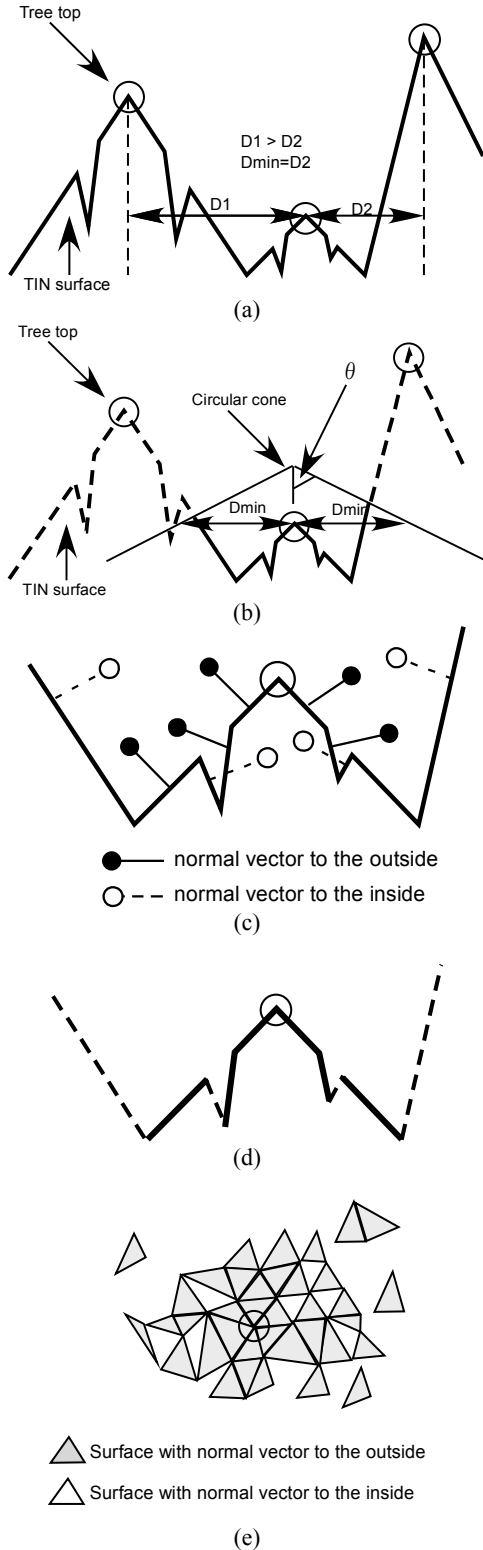


Figure 3. Conceptual diagram of the steps of the search area; (a) Calculation of D_{min} , (b) creation of the circular cone as a base

twice D_{min} and extraction of TINindividual, (c) calculation of the surface normal plane against the estimated tree top position, (d) the extraction of TINindividual with the surface normal vector to the outside and (e) the extracted search area.

4.2.3 Edge detection

The extracted TINindividual includes the surface of the crown and points other than the crown, so the following steps were carried out to detect only points of the crown. Figure 4 (a), (b) and (c) stand for the conceptual diagram of the edge detection.

- 1) The distance between the tree top position and the points in the extracted TINindividual was calculated and the furthest point was selected as the start point in order to search edge points.
- 2) Then, clockwise point connected to the start point was searched and set as the next start point.
- 3) The procedure stopped when the search point corresponded with the first start point.
- 4) The detected points were defined as the crown delineation of the tree crown with the selected tree top position.

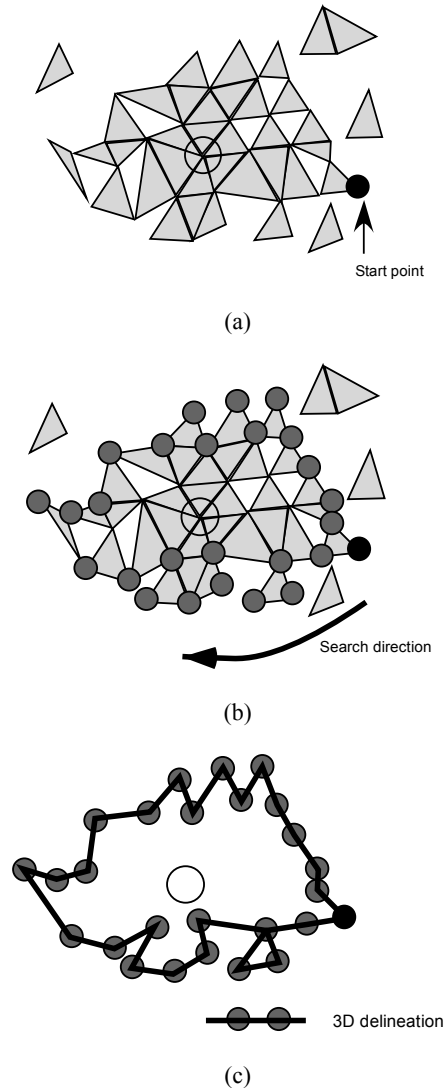


Figure 4. Conceptual diagram of the procedures of the edge detection; (a) set the start point for the creation polygon of

crown delineation, (b) searching outer points, and (c) the extraction of 3D delineation.

4.2.4 Post processing

The following steps were conducted to avoid overlap of the estimated crown delineations and to delete the overestimated tree tops.

- 1) The points inside the estimated crown delineation were deleted from the LiDAR raw data.
- 2) If the estimated tree top position was inside the estimated crown delineation, the corresponded tree top was deleted from the list of tree top positions.
- 3) The procedures from 4.1.1 to 4.2.4 were repeated until the end of list of tree top positions.

5. RESULTS AND DISCUSSION

The results derived from our algorithm are shown in Figure 5 and Figure 6.

Figure 5 (a2) shows the result of an isolated poplar tree that has tree crown with small size. The crown delineation of the poplar tree was well estimated, since the edge line was extracted around the tree crown. By visual inspection, our algorithm was able to estimate the crown delineation of tree crown such as conical shape and bowl shape with the smoothed surface regardless of size of tree crown. In the case of two adjacent trees by visual inspection, the boundary between trees in some cases was not separated correctly (See Figure 5 (b2)). Moreover, several crown delineations were overestimated on the same tree crown in case of broadleaf trees with the roughed surface (See Figure 6). A typical overestimation error is shown in Figure 6 (c). Each polygon was delineated at each cluster of shoot. To solve this error, it is necessary not only to improve the accuracy of the estimation method of the tree top position, but to improve the determination algorithm of the search area.

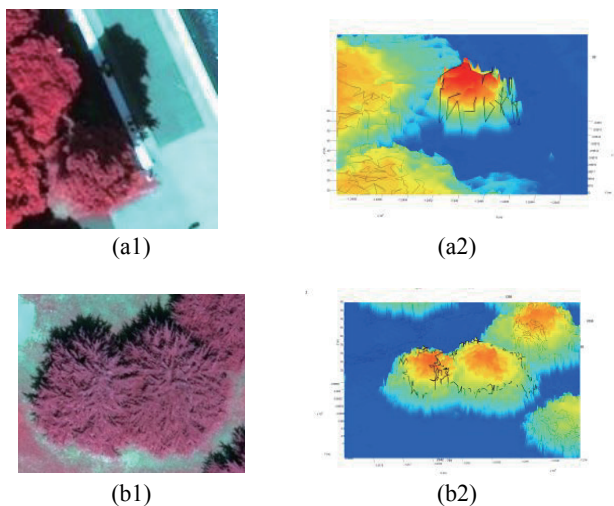


Figure 5. One of the results of the estimation of crown delineation. Image of the isolated poplar tree (a1), the estimated crown delineation of the poplar tree (a2), image of two conifer trees (b1) and the estimated crown delineation of two conifer trees (b2).

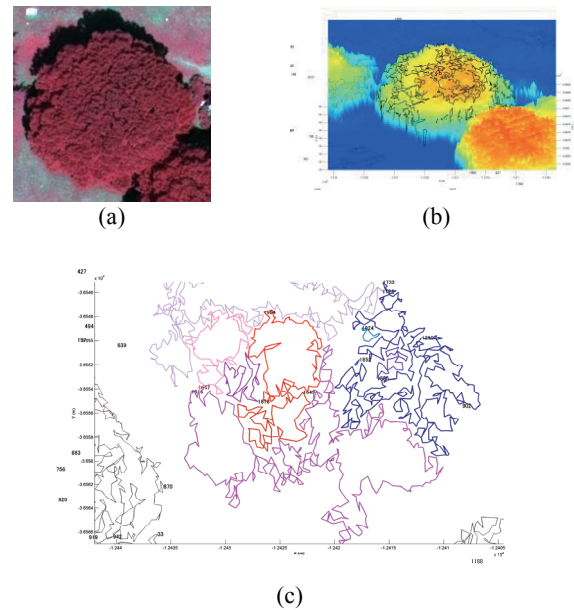


Figure 6. Typical error of the method. Image of a broadleaf tree (a), the estimated crown delineation of a broadleaf tree (b) and the estimated crown delineations of the crown (c).

6. CONCLUSIONS

The methodology described in this paper showed the potential of implementing vector-based algorithms as a tool to reconstruct tree crown shape. The algorithm was tested in a park forest which includes various tree crown sizes. The results indicate that the developed algorithm was able to avoid the effect of holes on the tree crown area and was able to delineate the isolated tree crown regardless of tree crown size. However, the problem of overestimation still remained. One possible improvement is to merge the overestimated delineations using the shape of the adjacent delineations.

References

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