ROBUST EXTRACTION OF ANCIENT BURIAL MOUNDS IN BRUSHLAND FROM LASER SCANNING DATA

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ABSTRACT:

Moroyama town, where is located in the southwestern part of Saitama Prefecture is a historical town including more than 80 ancient burial mounds. These ancient burial mounds locate in brushland. The diameters of these ancient burial mounds are about 5-15m, but there are small mounds less than 5m diameter which shows only top part of the mounds, bigger mounds more than 20m diameter and keyhole-shaped mounds. Therefore, it is supposed that some of the small ancient burial mounds are not yet found because the ancient burial mounds are covered with trees. The authors have been concentrating on developing an efficient extraction method for ancient burial mounds which are covered with trees using laser scanning data. However, filtering method and threshold values for robust extraction of the mounds from smaller to bigger are issues. With this motive, filtering and thresholding approach for an efficient extraction from smaller to bigger mounds using pyramid filters are proposed in this paper. The most remarkable points of this approach are its ability to extract from smaller and bigger mounds efficiently. In particular, the proposed pyramid filtering show the ability to extract smaller mounds less than 5m diameter, and 11 mounds are newly extracted by the method. Furthermore, in order to perform visual investigation, landscape animation for the mound area is generated in this paper.

1. INTORODUCTION

Tumulus period which have characteristics of huge grave occurred in Japan (around Kinki region) at the end of the third century. Huge graves were constructed as a symbol of the power in the country during early Tumulus period. After that, small burial mounds used to be constructed in all over the Japan at latter Tumulus period, from the end of 6th century to the 7th century. Therefore, there are many smaller and bigger mounds in Japan, and these mounds are indispensable for understanding the history and culture in those days.

However, it is supposed that some of the small ancient burial mounds are not yet found because the ancient burial mounds are covered with trees for long period of time. In generally, archaeological investigation for these small ancient burial mounds is performed taking great time and labor.

On the other hand, airborne laser scanner has been receiving more attention as a useful tool for real-time 3D data acquisition, and many applications such as city modeling, DTM generation, monitoring electrical power lines and detection of forest areas were proposed.

The authors have been concentrating on developing an efficient extraction method for ancient burial mounds which are covered with trees using laser scanning data. The proposed filtering method was a kind of median filter using elevation value, and it was verified that all known ancient burial mounds are extracted automatically and perfectly. However, filtering method and threshold values for robust extraction of the mounds from smaller to bigger were issues.

With this motive, filtering and thresholding approach for an efficient extraction from smaller to bigger mounds using pyramid filters are investigated in this paper.

2. CASE STUDY AREA

2.1 Historical town "Moroyama"

Moroyama town, where is located in the southwestern part of Saitama Prefecture is a historical town including more than 80 ancient burial mounds. There are 3 ancient burial mound groups which were called Oorui, Kawakado and Saido in Moroyama town. This is proof that the power had lived in Moroyama area in the latter the Tumulus period. Oorui and Kawakado are case study area of this investigation. Oorui ancient burial mound group is located in the northeast of Moroyama, and 39 ancient burial mounds including 2 keyhole-shaped mounds were confirmed. Kawakado ancient burial mound group is located in the southwest of Oorui, and 38 small ancient burial mounds in brushland along the Oppe river were confirmed. According to many relics which were discovered from the stone chamber in the ancient burial mound, it is thought that the ancient burial mounds in Moroyama area were constructed from the end of the 6th century to the 7th century. Furthermore, it is also realized that the surface of the ancient burial mounds were covered with about 20cm diameter stones.

These ancient burial mounds locate in brushland. The diameters of these ancient burial mounds are about 5-15m, but there are small mounds less than 5m diameter which shows only top part of the mounds in Kawakado, bigger mounds more than 20m diameter and keyhole-shaped mounds in Oorui. Therefore, it is supposed that some of the small ancient burial mounds are not yet found because the ancient burial mounds are covered with trees and archaeological investigation does not accomplish. Figure 1 shows one of the small ancient burial mounds.

Figure 1. Small ancient burial mound (kawakado area)

2.2 Laser Scanner System

In generally, laser scanning data which is acquired by airborne is strongly influenced by covered vegetation such as the trees and grasses. Therefore, helicopter laser surveying was performed in defoliation time during the winter season (January 31, 2007).

Table 1 shows the specification of laser scanner system.

Platform	Helicopter (AS-350BA)
Model No of the system	ALTM3100-AG4(Optech Co.,)
Laser wave length	1064nm(Nd:YAG)
Pulse repetition frequency	100,000Hz
Scan frequency	70Hz
Scan angle	±30°
Beam divergence	0.25mrad
Accuracy	Horizontal:1/3000* Altitude(m) Vertical:±0.15m/shot

Table 1. Specification of laser scanner system

3. EXTRACTION OF ANCIENT BURIAL MOUND

3.1 Spatial filter based on height difference

In generally, airborne laser scanning enables to acquire point cloud 3D data using laser pulses which are reflected from the surface of the ground or objects. In order to generate DTM from point cloud 3D data, the trees, houses and the other objects also should be removed by filtering. Filtering of point cloud 3D data which were collected by airborne laser scanner means removing of the height-values such as trees, houses and the other objects, and various filtering methods have been developed, e.g., morphological filtering using weights depending on the window sizes (Kilian, et. al. 1996), using function consist of height difference and distance between two points (Vosselman, 2000), using standard deviation image (Lohman, et. al. 2000). Furthermore, filtering using first and last return height (Alharthy & Bethel, 2002), filtering using energy function by height difference (Elmqvist, 2002), alternative the deepest points and height difference, filtering using slope angle for a piecewise planar surface (Sohn & Dowman, 2002) were developed respectively.

However, robust filtering for extraction of small mounds in blushland from point cloud 3D data collected by airborne laser surveying is still issue because of covered trees. In order to extract the ancient burial mounds, the trees, houses and the other objects also should be removed by filtering, while the small mounds are preserved. With this motive, spatial filter based on height difference was investigated (Kakiuch, 2007). The spatial filter is a kind of median filter using elevation value, and the filter have ability to remove the height data for the interest point by following equation.

$$|h_i - h_c| < h_0 \tag{1}$$

where h_i = elevation value
h_c = median value
h_0 = height threshold

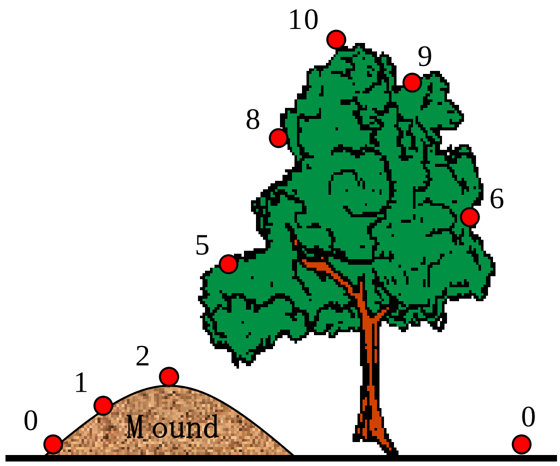

Figure 2(a). Principles of the spatial filter

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	5	6	0	0	0	0	0
0	0	0	1	1	5	6	8	0	0	0	0
0	0	1	1	6	8	9	7	5	0	0	0
0	0	1	2	5	8	10	9	6	0	0	0
0	0	1	2	7	8	9	7	8	0	0	0
0	0	1	1	1	1	6	8	5	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

Figure 2(b). Cross section view of measurement points

Figure 2(a) shows the principles of the proposed filtering. The circles in figure 2(a) show the measurement points, and the numerical values show the elevation value (m).

Figure 2(b) shows the cross section view for the measurement points from the airborne laser scanner, and black square shows window size in the case of 7×7 mask.

In this case, elevation value for the center of the window becomes 5m, and 1m becomes median value. Here, let assume 2m threshold value as height difference, height difference (4m) between elevation value for the center of the window and the median value shows large value than the height threshold, and the elevation value for the center of the window will be removed as a noise.

3.2 Pyramid filtering

Spatial filter based on height threshold have ability to remove the data for the interest point as a noise when the height value is larger than the threshold value. However, filtering for only small area is performed by small window size. Therefore, in order to remove trees, houses and the other objects efficiently, greater window sizes should be applied step by step as a pyramid filtering.

Main extraction flow for pyramid filtering are as follows.
1. Acquisition of point cloud 3D data by helicopter laser surveying.
2. DTM generation by pyramid filtering.
3. Extract shape of small ancient burial mounds from DTM by filtering and thresholding approach.

3.3 Generation of grid data

In generally, airborne laser scanning enables to acquire point cloud 3D data using laser pulses which are reflected from the surface of the ground or objects. Therefore, in order to adopt the proposed filtering, point cloud 3D data was converted into grid data from random data using the lowest height point in each grid (one gird size is 30*30cm).

On the other hands, the laser scanner systems have ability to acquire the first pulse data which are the pulse that returns first from the object, and the last pulse data which are the pulse that returns last from the object. In order to generate DTM, the last pulse data was used in this investigation since the last pulse data have ability to detect the surface.

Figure 4 shows the grid data as a colour gradation map, which was acquired using the last pulse data for Oorui area.

3.4 DTM generation by pyramid filtering

As the first step, in order to generate DTM for extraction of the ancient burial mounds, size for the ancient burial mounds in Oorui area were assumed as less than 2m in height and 5-15m diameter. This means that more than 2m height data should be removed as not ancient burial mounds.

However, filtering for only small area is performed by small window size. Therefore, in order to remove trees, houses and the other objects efficiently, greater window size were applied step by step as a pyramid filtering using following equation.

$$WS = 2k + 1 \qquad (2)$$

where WS = Window Size of filter
k = 1,2,3,… : Number of filtering

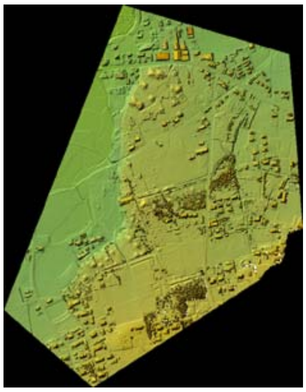

Figure 4. Gradation map by last pulse data (Oorui)

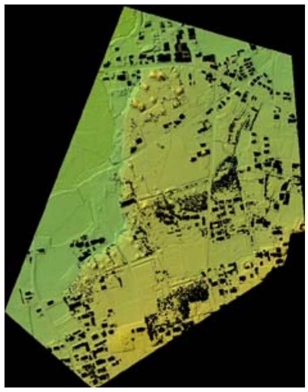

Figure 5. Result of filtering

Figure 5 shows the results of filtering using 2m height as a threshold value. These black areas show the removed area, and the ancient burial mounds should be being under 2m height.

However, these black areas contain part of the mounds when the mound is covered with trees. Therefore, in order to interpolate black areas efficiently, the black areas were interpolated using the median value in the window area in this investigation.

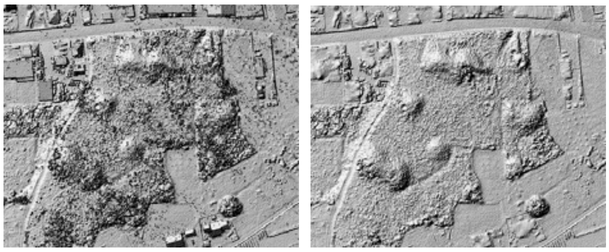

Figure 6. Result of pyramid filtering with interpolation (Left: Before filtering, Right: After filtering)

Figure 6 shows result by the pyramid filtering with interpolation. It can be seen that the trees, houses were removed. Furthermore, it is understood that small mounds were appeared.

Figure 7 shows the filtering results for whole area. Similarly, it can be seen that the trees, houses were removed.

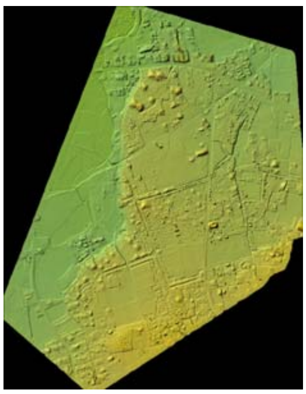

Figure 7. Filtering result for whole area

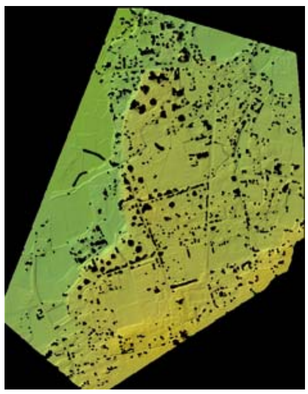

Figure 8. Extracted candidate of ancient burial mounds

3.5 Extraction of small mounds

As the next step for extract small mounds, filtering with 0.2m threshold was performed using 51×51 window size (one grid size is 30*30cm) under assumption that the height of the ancient burial mounds is larger than 0.2m and less than 2m. This means that more than 0.2m height data should be extracted as small mound. Figure 8 shows the extracted small area (black area) which is larger then 0.2m and less than 2m height.

It can be seen that the ancient burial mounds were extracted efficiently. However, these black areas show only candidate for small mounds. In order to extract the small mounds, each black area was evaluated using the "Area" and "Circle Ratio" under estimation that the shapes of small mounds show round shape with 5-15m in diameter.

$$\begin{aligned} &\text{Area} = \pi r^2 \\ &\text{Perimeter} = 2\pi r \\ &\text{Circle Ratio} = 4\pi(\text{Area})/(\text{Perimeter})^2 \end{aligned} \tag{3}$$

where π = ratio of circumference of circle to its diameter
r = radius

On the other hands, small mounds less than 5m diameter which shows only top part of the mounds, and bigger mounds more than 20m diameter and keyhole-shaped mounds in Moroyama area were discovered by recent archaeological investigation. With this circumstances, filtering and thresholding approach for an efficient extraction from smaller to bigger mounds using pyramid filters were investigated.

As the first step in the pyramid filtering, in order to extract the small ancient burial mounds less than 5m diameter which shows only top part of the mounds, 51*51 window size (one grid size is 30*30cm) was adopted. Furthermore, extracted areas are reduced using area value (7m^2) and circle ratio (0.8).

Figure 9 shows the result of extraction. These red areas show the extracted areas as the small mounds using geometric threshold (area > 7m^2 and circle ratio > 0.8). It can be found that the small black area and irregular area were removed as except of the small mounds.

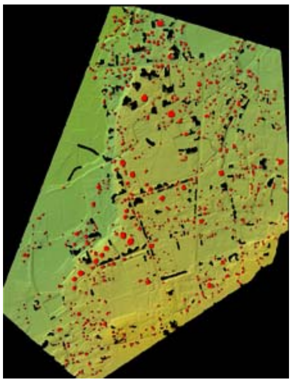

Figure 9. Result of extraction

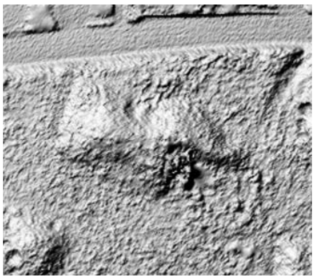

Figure 10. Keyhole-shaped mounds

However, it can be seen that the Keyhole-shaped mounds were not extracted because of its shape were destroyed by weathering (figure 10). The value of 0.5 was computed as circle ratio for the destroyed Keyhole-shaped, furthermore it can be found that the original shape of the mounds remains around the top parts.

In order to extract the Keyhole-shaped mounds, 0.5 height value was adopted and filtering was performed for the black areas in Figure 9 using 101*101 window size, and the extracted areas were reduced using threshold perimeter (>0.5).

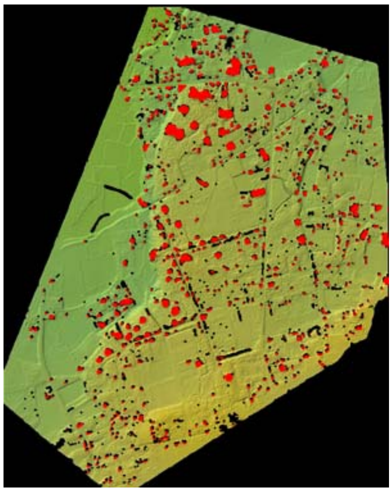

Figure 11. Final results of extraction

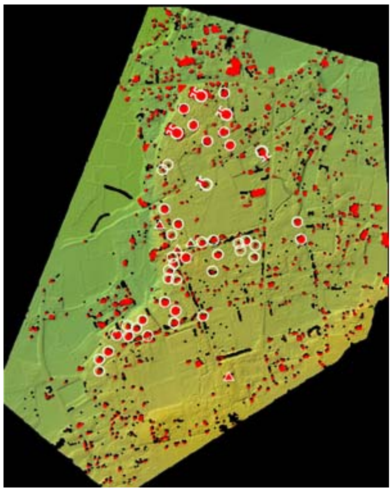

Figure 12. Evaluation of extraction

Figure 11 shows the final results. It can be found that the small round area or irregular area were removed as except of the ancient burial mounds.

In order to evaluate final results, the position for the known ancient burial mounds were marked with white circle on the figure 12. As a result, it can be found that many candidate areas as the ancient burial mounds were extracted. Furthermore, it can be confirmed that all known ancient burial mounds were extracted perfectly.

4. EVALUATION OF FILTERING

In order to evaluate the proposed filtering method, the proposed filtering method was applied to Kawakado area using the same procedures. Figure 13 shows the result and the known mounds were marked with white circle on figure 13. Similarly, it can be seen that all known ancient burial mounds were extracted perfectly. Furthermore, 11 mounds were newly extracted by the field surveying for the extracted candidates. For example, the small mound with 0.5m height (figure 14) marked with double white circle on figure 13 shows unknown mound still our investigation. Figure 15 shows the excavation site of the new mound. These new mounds are shown with white triangle on figure 13.

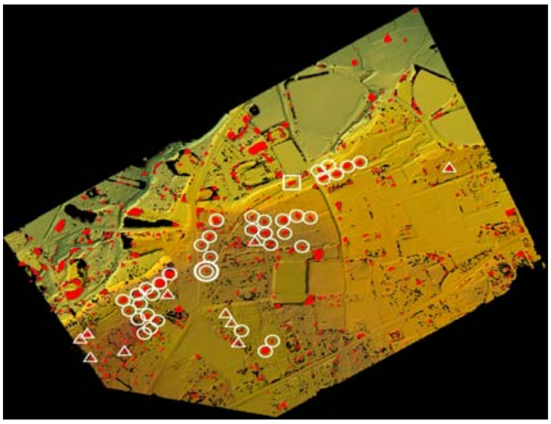

Figure 13. Final extraction result (Kawakado)

Figure 14. New mound in Kawakado

Figure 15. Excavation site of the ancient burial mound

Figure 16. Same characteristic of the ancient burial mound

On the contrary, figure 16 shows one of extracted mound candidate which does not the ancient burial mound. Therefore, it can be said that the proposed filtering methods have ability to extract topography which have the same geometric characteristics of the ancient burial mound. In other wards, the proposed filtering method is robust method to extract topography which have the same characteristic of the ancient burial mound.

5. VISUALIZATION

Recently, 3D visualization has been receiving more attention as a useful method to understand engineering phenomenon intuitively, or to find out important elements that we can't detect in usual simulation. Furthermore, visualization under virtual environment is efficient method from the view point that people can appreciate or experience the archaeological objects or historical space through the computer.

In order to perform visual investigation, landscape animation for the mound area is generated.

Figure 17 shows the distribution of ancient burial mounds in Kawakado and Figure 18 shows one of scene for 3D animation for Kawakado area. It is understand that the small mounds were constructed along terrace for staying away of flood disaster.

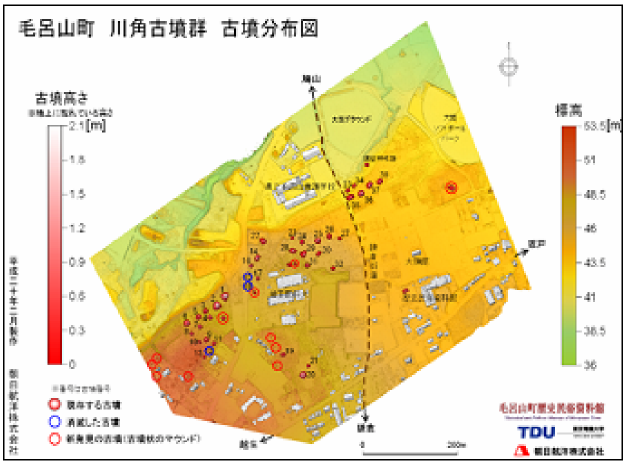

Figure 17. Distribution of ancient burial mounds map

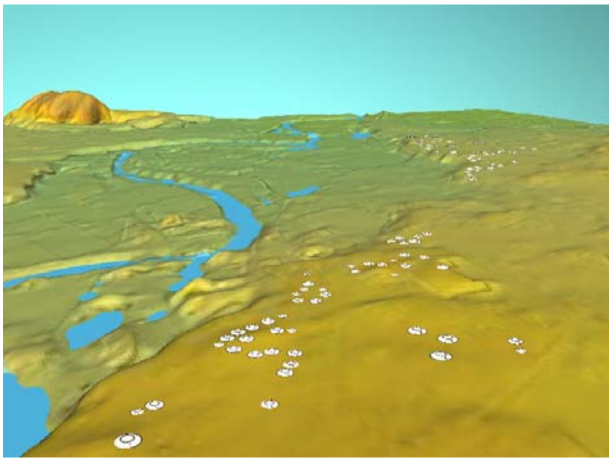

Figure 18. 3D animation for Kawakado area

6. CONCLUSIONS

Airborne laser surveying is one of the efficient methods to extract the ancient burial mounds which locate in brushland. In generally, the more high dense 3D data and the more flexibility can be acquired with lower speed. Therefore, archaeological investigation for the small ancient burial mounds, helicopter laser surveying was performed, and filtering method for extraction of the ancient burial mounds was proposed in this investigation.

As the result, it was verified that all ancient burial mounds are extracted automatically and perfectly by the proposed filtering method based on height difference. Furthermore, the proposed filtering method was applied to Kawakado area, and it was also confirmed that all known ancient burial mounds including keyhole-shaped mound are extracted perfectly.

The most remarkable points of this approach are its ability to extract from smaller and bigger mounds efficiently. In particular, the proposed pyramid filtering show the ability to extract smaller mounds less than 5m diameter, and 11 mounds are newly extracted by the method. Furthermore, in order to perform visual investigation, landscape animation for the mound area was generated in this paper. It was realized from 3D animation that small mounds were constructed along terrace for staying away of flood disaster area. Consequently, it is concluded that the proposed filtering methods is expected to become robust method in the various size of mound extraction. Furthermore, 3D animation will contribute to institutive understanding.

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