# NEW METHOD TO GENERATE EXCAVATION CHARTS BY OPENNESS OPERATORS

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### **ABSTRACT:**

Openness operation to digital elevation model (DEM) is effective to extract topographical features, Yokoyama et al (2002). There are two kinds of openness. One is positive openness adapted to extract ridge lines, and the other is negative openness to extract valley lines. This paper describes a new method of chart generation for archeological relics and remains by applying those openness operators. The proposed method has advantages such as (1) The chart relevantly describes the features and reliefs of object, (2) The chart generation is undertaken by computer, (3) The charts from different viewpoint are conveniently generated by applying 3D display technique.

### 1. INTRODUCTION

Recently, cultural assets such as relics and remains are recorded by using 3D geometry measurement technology. The measured 3D data is exhibited for general public as well as experts so that they can observe real cultural assets although they do not go to the particular places.

Generally 3D data has been shown by using reliefs. The relief representation is effective to grasp the direction of faces intuitively, although it cannot express feature lines of shapes such as ridge lines or valley lines, which are important to grasp the shape of cultural assets.

In the field of topography, "openness" is proposed as the amount of terrain features, used for extracting ridge lines and valley lines from digital elevation model (DEM). In this paper, we propose a new method to create excavation charts to record cultural assets by using the openness operation.

#### 2. METHODS

Our method represents terrains as the three representation methods –openness, relief and graduated elevation coloring-are selected and overlaid. Although each of the three methods has merits and demerits, overlaying the obtained images makes up for the demerits each other so that the features of cultural assents can be represented very clearly.

Calculating a DEM creates each of the three methods. In the DEM, a terrain is divided into a grid and the elevation at every grid point is recorded in an array (Burrough, 1986).

The following sections describe the three methods with respect to representation, data creation, and merits and demerits of terrain representation.

#### 2.1 Relief

Relief represents the direction of ground surfaces (Burrough, 1986) and is calculated as the angle between the direction vector of the light source and the normal vector of the ground surface. Figure 1 shows the DEM around Mount Hayachine in Iwate Prefecture to which relief operation was applied with the light source set in the northwest direction. The relief is shown in grayscale, where the smaller the angle is, the whiter the surface is colored.

The merits of the relief are intuitive grasp of the direction of ground surfaces and clear representation of terrain features. In particular, when the surface direction changes in parallel to the light source direction, the terrain features (for example, ridge and valley lines going from northeast to southeast) can be clearly represented. The demerits of the relief are: (1) elevation cannot be represented and (2) feature lines such as ridge and valley lines cannot be extracted.



Figure 1. Relief image

### 2.2 Openness

Openness is the quantified terrain sight (Yokoyama et al., 2002), calculated by using the terrain line-of-sight principle. There are two kinds of openness operation: One is positive openness adapted to extract ridge lines, and the other is negative openness to extract valley lines. Figure 2 shows the overview of the ridge line operation, where the sight in the air is quantified so that greater values represent ridge lines. Figure 3 shows the overview of the valley line operation, where the sweep under the ground is quantified so that greater values represent valley line operation and Figure 5 shows the result of the ridge line operation of the data shown in Figure 1. Figures 4 and 5 show grayscale images, where the greater the value is, the whiter the line is colored.

The merit of openness is that ridge and valley lines can be extracted although they spread in any directions. The demerit is that the elevation and the direction of ground surfaces cannot be represented.

Here note that 3D data of relics and remains has the following two characteristics in comparison to terrain data: (1) features of ridge and valley lines do not appear so clearly and (2) data noise is large with respect to the clearness of the features. Therefore, we arranged the method of Yokoyama et al, 2002 so that (1) feature lines would be shown more clearly and (2) influence of data noise would be decreased.



(Yokoyama et al, 2002)



Figure 4. Openness (Ridge line operation)



Figure 5. Openness (Valley line operation)

#### 2.3 Graduated elevation coloring

Graduated elevation coloring is created as the data of elevation is classified and each class is colored (Burrough, 1986). Figure 6 shows the result of graduated elevation coloring of the data of Figure 1. The lower the elevation is, the deeper the green level will be; and the higher the elevation is, the deeper the brown level will be.

The merit of graduated elevation coloring is that broad distribution of elevation can be grasped. The demerit is that the direction of ground surfaces and ridge and valley lines cannot be represented clearly.



Figure 6. Graduated elevation coloring

#### 2.4 Combination of the representation methods

Our method selects two or more of the four representation methods (relief, openness (ridge line), openness (valley line) and graduated elevation coloring) according to the features that must be emphasized. Since the relief is effective to grasp surfaces intuitively, it is used as the basis of representation for every combination. With the rest of the three methods, eight combinations can be defined. As we examined all the eight combinations, we found that three combinations were notably effective to represent cultural assets. Each of the three effective combinations is described below. Note that it is important to color the result of each representation method in different colors to perceive each method uniquely.

### (1) Combination 1: Relief + ridge line

This combination is effective to represent relics since they are usually recognized by reading ridge lines. On the background of the relief colored in brown, grayscale ridge lines are overlaid. The darker the gray level is, the steeper the ridge lines are.

#### (2) Combination 2: Relief + ridge line + valley line

This combination is effective to represent angular objects. On the background of the relief colored in brown, the ridge lines colored in blue and grayscale valley lines are overlaid. The darker the color is, the steeper the ridge and valley lines are.

(3) Combination 3: Relief + valley line + graduated elevation coloring

This combination is effective to represent remains rising from the ground surface. On the background of the grayscale relief, the graduated elevation coloring is overlaid, where the lower elevation is colored in green and the higher elevation is colored in brown. On the relief and the graduated elevation coloring, the valley lines colored in blue are further overlaid. The darker the blue level is, the steeper the valley lines are.

#### 3. DATA USED

To apply our method to relics and remains, these 3D objects must be measured to convert to DEMs. The data listed below were prepared to examine our method.

#### [A] Relics

- (1) Sample 1: Lithic Type: Stone spear Excavated in: Aomori pref., Japan Created in: Jomon Period Measured by: Indoor-type laser 3D profiler developed by LANG
- (2) Sample 2: Earthenware fragment Type: Fragment of Jomon ware Excavated in: Iwate pref., Japan Created in: Jomon Period Measured by: Indoor-type laser 3D profiler developed by LANG
- (3) Sample 3: Wooden product (water well frame) Type: Water well frame created by hollowing out a log Excavated in: Iwate pref., Japan Created in: Heian Period Measured by: Indoor-type laser 3D profiler developed by LANG

#### [B] Remains

(4) Sample 4: Stonewall
Type: Castle wall created by heaping up stones
Excavated in: Iwate pref., Japan
Created in: Edo Period
Measured by: Outdoor-type laser 3D profiler of Leica
Geosystems

(5) Sample 5: Stone circle
 Type: Stone circle
 Excavated in: Iwate pref., Japan
 Created in: Jomon Period
 Measured by: Outdoor-type laser 3D profiler of Leica
 Geosystems

### 4. RESULT

Our method was applied to the data described in Chapter 3. The light sources of the reliefs are set in northwest.

### (1) Sample 1 (lithic)

Figure 7 shows the result where combination 1 was applied to sample 1 developed in the charts viewed in the six directions. Figure 8 shows the enlarged view of the rectangle area of Figure 7. From Figures 7 and 8, we can obtain the following information. The relief represents the removed surfaces created by hammering. In the removed surfaces, there are concentric ripple shapes. According to the direction of the ripple, we can assume the direction of hammering. The ridge lines clearly show the boundary lines of removed surfaces. Combination 1 can represent both the shape of the lithic and the features of the technique to create the tool at the same time.



(2) Sample 2 (Earthenware fragment)

Figure 9 shows the result where combination 1 was applied to the front side of sample 2. Figure 10 shows the enlarged view of the rectangle area of Figure 9. From Figures 9 and 10, we

Figure 8. Enlarged view of sample 1 (Lithic)

10mm

can obtain the following information. The relief represents moderate undulation on the surface of the fragment. Jomon ware has twisted-rope patterns on its surface. The ridge lines represent fine undulation of ropes. We can see the unit of rope application and the direction of the rope fibers. Combination 1 can represent both the structure of the pot and the features of the decoration technique at the same time.



Figure 9. Sample 2 (Earthenware fragment)



Figure 10. Enlarged view of sample 2 (Earthenware fragment)

### (3) Sample 3 (wooden product)

Figure 11 shows the result where combination 1 was applied to the surface of sample 3 developed using the cylindrical map projection. Figure 12 shows the enlarged view of the rectangle area of Figure 11. From Figures 11 and 12, we can obtain the following information. The relief represents the surface of the log that a tool shaved off. The ridge lines clearly represents the boundary of shaved faces, which helps to observe the unit of shaving. Combination 1 represents both the undulation of the entire remain and the condition of the work at the same time.



Figure 12. Enlarged view of sample 3 (wooden product)

#### (4) Sample 4 (Stonewall)

Figure 13 shows the result where combination 2 was applied to sample 4. Figure 14 shows the enlarged view of the rectangle area of Figure 13. From Figures 13 and 14, we can obtain the following information. The relief represents the stereoscopic stones heaped up. The ridge and valley lines clearly represent the profiles of the stones and the traces of the wedges driven into the stones to hew out them. The wedges can be seen in the red circles of Figure 14. Combination 2 represents both stereoscopic effect of the structure and the fine condition of the work at the same time.



Figure 14. Enlarged view of sample 4 (stonewall)



Figure 11. Sample 3 (wooden product)



Figure 13. Sample 4 (Stonewall)

#### (5) Sample 5 (stone circle)

Figure 15 shows the result where combination 3 was applied to sample 5. From Figure 15, we can obtain the following information. The relief represents the stereoscopic ground surface and stones. The valley lines represent the profiles of the protruding stones. The graduated elevation coloring represents the relative elevation between the ground and the stones. Combination 3 represents undulations of the entire remain, distribution of elevation and the profiles of each component at the same time.



Figure 15. Sample 5 (stone circle)

# 5. DISCUSSION

According to the results described in Chapter 4, our method enables the effective representation of cultural assets. The relief enables stereoscopic representation of undulation of entire objects. The openness clearly represents the condition of the work on the surfaces and the boundaries of components. The graduated elevation coloring enables intuitive grasp of elevation distribution of remains. Combining these representation methods enables clear representation of various cultural assets, which helps archeologists perceive a lot of information. Through the examination in Chapter 4, our method can be regarded as the effective representation method of cultural asset records that meet archeologists' requests. In addition, our method inherits the advantage of digital data. Orthographic record drawings can be created quickly and objectively since the object data is calculated from DEM. As the projection plane is adjusted when 3D data is converted to DEM, record drawings can be created from arbitrary viewpoints.

## 6. CONCLUSIONS

Our method can clearly represent the feature lines and the shapes of objects as the relief, openness (ridge and valley lines) and the graduated elevation coloring are effectively overlaid. It is available to combine suitable representation methods according to the features of objects.

Since the openness can extract the condition of the work on the surface of objects quantitatively, it is expected that our method can be used as the tool for understanding the shapes of cultural assets, as well as the new representation method of 3D data.

#### **References from Journals:**

Yokoyama, R., M. Sirasawa and R. Pike, 2002. Visualizing topography by openness: A new application of image processing to digital elevation models, Photogrammetric Engineering & Remote Sensing, Vol. 68, No. 3, pp. 257-265.

#### **References from Books:**

P. A. Burrough, 1986. Principles of geographical information systems for land resources assessment, Oxford University Press.

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