A study of the compound evaluation for geophysical explorations by self-organizing maps

著者	Nakamura Masako, Kusumi Harushige, Yamamoto Tatsuru, Yamamoto Tsuyoshi, Tsuji Takeshi
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A study of the compound evaluation for geophysical explorations by self-organizing maps

M. Nakamura, H. Kusumi & T. Yamamoto
Department of Environmental and Urban Engineering, Kansai University, Osaka, Japan

T. Yamamoto
Kinki Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Osaka, Japan

T. Tsuji
Department of Environment and Resource System Engineering, Kyoto University, Kyoto, Japan

ABSTRACT: In Japan, in the high economic growth period in 1960's, a great number of cutting ground and embankment slopes were formed to construct many roads. They have been aging now, it is important to estimate the health of them and maintain effectually. So, in situs, we usually carry out many kinds of the geophysical exploration. However, there is not the technique to compound and interpret the result of each geophysical exploration in a numerical formula of the engineering now. Therefore, we notice to self-organizing maps (SOM) used widely in a field of the information processing engineering, and tried to interpret multidimensional data by integrating. In this paper, we classified the ground property by SOM. The classification result is relatively conformal with boring data. Therefore, it is recognized that it can be used to improve the interpretative accuracy of compound geophysical explorations.

SUBJECT: Site investigation and field observations

KEYWORDS: monitoring, field measurements, rock slopes and foundations, neural network, rock properties

1 INTRODUCTION

In the investigation of the soundness of aging slopes, the geophysical exploration that makes the underground visible in a nondestructive way by using various physical phenomena attracts attention. With physical information on the natural ground by a single geophysical exploration, there is a limit to interpret the state of the natural ground, therefore two or more geophysical explorations are often used to make up for the interpretation limit. Then, we propose the method of evaluating the ground by converting into the porosity and the saturation fraction from the seismic velocity and the resistivity. However, since even two physical values are not enough, it is preferable to make a complex evaluation with different physical values in addition. Therefore, in this paper, we focused on SOM which is widely used in the field of information processing engineering. There were only some cases of the ground evaluation by SOM, so, in this paper, the adaptability to the ground properties evaluation of the aging slope was examined. The result of the classification by SOM was able to be related to the rock kind and the rock class division that became clear in the boring investigation. Therefore, it was able to show that this method was effective for the improvement of the interpretative accuracy of compound geophysical exploration

2 GEOLOGICAL CONDITIONS IN THE RESEARCHED SITE

An analytical object in this research is a cutting ground slope along the national road No.9 in Fukuchiyama City in Kyoto in Japan. Figure 1 shows topographic features of the slope, and Figure 2 the view of the shotcrete slope (A-district) and Figure 3 the view of the non-support slope (B-district). These are near the south of the national road, and comparatively large-scale slopes of about 200m in length and about 50m in height. The shotcrete slope is distributed in the eastern part of the slope, and the non-support slope in the western part of it. There were a lot of cracks, a lot of vegetation from the cracks and swells on the surface of the slope with shotcrete due to aging. Although the non-support slope was a naked ground slope, there is hardly a big transformation that could be seen. Geological features in this site are in Tanba strata at Triassic in the Mesozoic-Jurassic Period, and they are chiefly composed of sandstone layer, a sandstone shale alternation of strata, and a green rock layer.

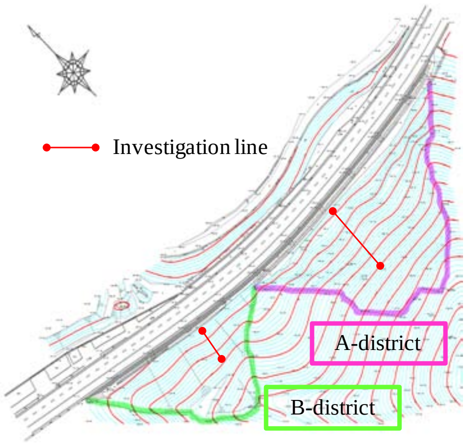


Figure 1. Topographic features of the slope

Figure 2. View of the shotcrete slope (A-district)

Figure 3. View of the non-support slope (B-district)

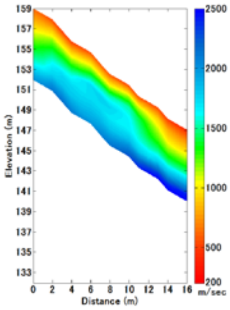


Figure 4. Distribution of P-wave velocity

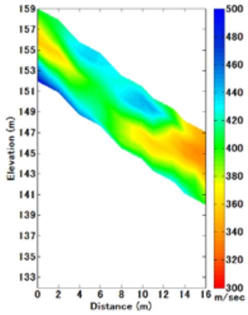


Figure 5. Distribution of S-wave velocity

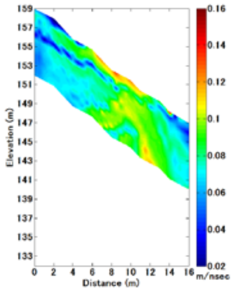


Figure 6. Distribution of Electromagnetic-wave velocity

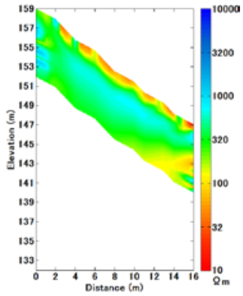


Figure 7. Distribution of Resistivity

3 GEOPHYSICAL EXPLORATIONS

In situ, the seismic tomography method, the surface wave method, the electromagnetic wave tomography method, and the resistivity tomography method were executed. In both A-district and B-district, they were executed 4 times in total from 2008 to 2009. As for A-district, geophysical data were not sensitive enough to evaluate the geological structure, influenced by the shotcrete and metal bodies behind the shotcrete. Therefore, the result of the B-district was used for the evaluation by SOM. The fourth measurement result (winter 2009) in B-district is shown from Figure 4 to Figure 7. Figure 4 shows the distribution of the P-wave velocity obtained by the seismic tomography method. This shows the tendency that the speed transmitted in the ground becomes high as depth becomes deep. Figure 5 shows the distribution of the S-wave velocity obtained by the surface wave method, and a low-speed area is seen at about 4m in depth. Figure 6 shows the distribution of the electromagnetic-wave velocity obtained by the electromagnetic tomography method. Because the electromagnetic velocity is related to the water content in the ground, it is shown the high percentage of water is contained if the electromagnetic velocity is low, and that the low percentage of water is contained if it is high. Figure 7 shows the distribution of the resistivity obtained by the resistivity tomography method. A low resistivity near the surface of the slope is seen and a high resistivity in the middle depth.

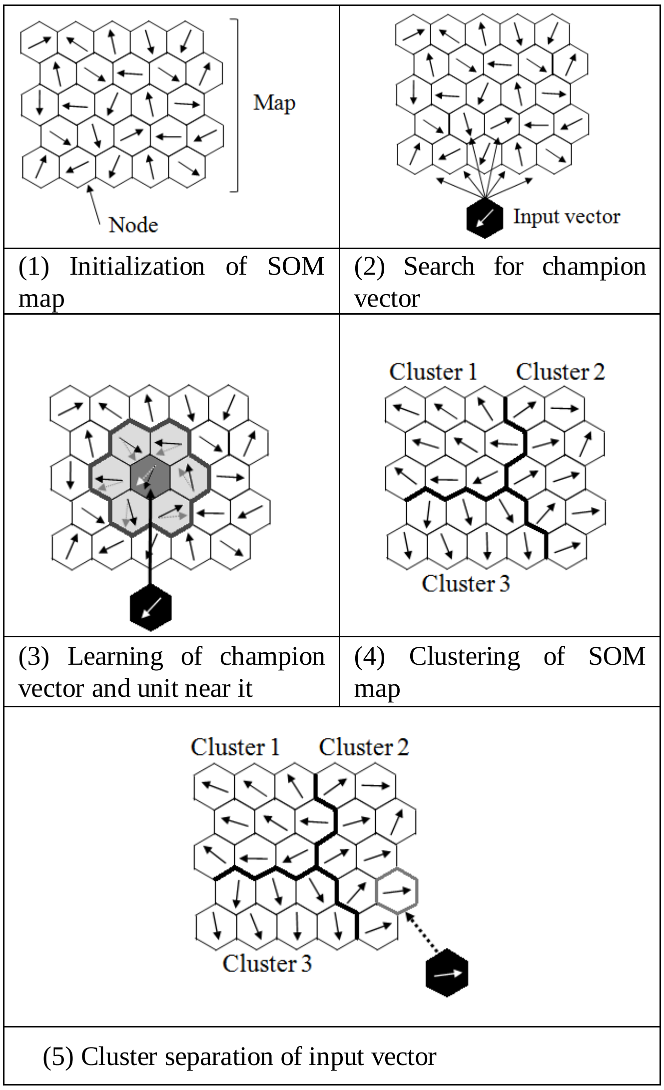
4 AN EVALUATION METHOD

4.1 *The outline of SOM*

SOM is a kind of the neural net work developed by professor Kohonen in Helsinki university. This has the feature in which the input data of higher dimension can be mapped to SOM plane of two dimensions in proportion to the degree of similarity. SOM makes a map that data with a similar feature are arranged near and data with a different feature are arranged distantly, and higher dimensional data are mapped to 2 dimensional plane. As a standard shown the degree of similarity, Euclidean distance between data is used, and it is judged that the degree of similarity is high if Euclidean distance is small. Moreover, with SOM, clustering is possible without a teacher of data. The flow of the algorithm of SOM is shown in Figure 8. First of all, the two-dimensional map is initialized. The reference vectors with the same dimension as the input vectors are arranged in two dimensional SOM plane at random. Secondarily, we search for the champion vector that Euclidean distance shown in the expression (1) is minimized. In a word, we look for the most similar reference vector to the input vector.

$$d = \left\| x_i - m_j \right\| = \sqrt{\sum_{k=1}^{n} \left[x_{ik} - m_{jk} \right]^2} \tag{1}$$

Where, x_i: the input vector; m_j: the reference vector.



(1) Initialization of SOM map

(2) Search for champion vector

(3) Learning of champion vector and unit near it

(4) Clustering of SOM map

(5) Cluster separation of input vector

Figure 8. The flow of the algorithm of SOM

Thirdly, according to the expression (2) shown below, we make the champion vector and the circumference vectors near the champion vector learn the input vectors.

$$m_i(t+1) = m_i(t) + h_{ci}(t)\left[x(t) - m_i(t)\right] \qquad (2)$$

Where, $m_i(t)$: information processing ability; $h_{ci}(t)$: the update rate; $x(t)$: the input vector; t : the learning frequency. The neighborhood size is reduced as the learning progresses. Repeating the search of the champion vector and learning a number of times, vectors with high similarity are arranged adjacently on the two-dimension map, and it is possible to cluster the two-dimension map. Finally, by applying the input vectors to the clustered two-dimension map, it is confirmable into which cluster the input vectors are classified.

4.2 *Classification method*

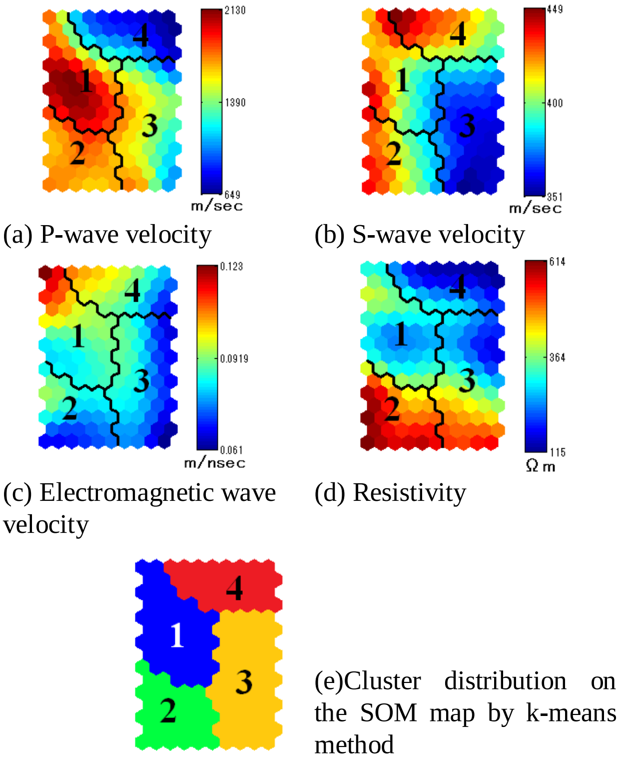
In this paper, k-means method was used to cluster objectively. k-means method sets the number of divided clusters prior to classification. As is the characteristic of the calculation of k-means method, only the local optimum solution can be obtained, so a few differences are caused in the final result by the central positions of an initial cluster in bottom-line. Then, DB-index shown in the expression (3) as an evaluation function was used to judge the best classification. Classifications by k-means method were executed in various patterns, and the result of minimizing DB Index was decided as an appropriate classification result. In this paper, to interpret a final classification result easily, the number of divided clusters was set to 4.

$$DBindex = \frac{1}{k}\sum_{i=1}^{k}\max_{i\neq j}\left\{\frac{\Delta(X_i)+\Delta(X_j)}{\delta(X_i, X_j)}\right\} \qquad (3)$$

Where, k: Number of clusters; $\delta(X_i, X_j)$: Euclidean distance between centers of cluster X_i and X_j; $\Delta(X_i)$: Euclidean distance between the center of cluster X_i and each cluster.

5 CLASSIFICATION OF GEOPHYSICAL DATA BY SOM

In this paper, the classification result of the geophysical data measured in winter 2009 is shown as compound evaluations. Cluster distribution of physical values on the SOM map by k-means method is shown in Figure 9. The SOM map has no relation to the coordinates in the vertical and the horizontal direction of two dimensional plane, and it merely arranges similar data in a small distance. In Table 1, a relative amount of the geophysical value in each cluster is shown by the number of [●]. The comparison of the classification result and the ground information by the boring investigation are shown in Figure 10. In the classification result, the cluster 4 is corresponding to the area that RQD is 0% and that the rock class is D-CL class, and the P-wave velocity and the resistivity are low and the Electromagnetic-wave velocity is high as shown in Table 1. Therefore, it is thought that the cluster 4 is the area where the possibility of cracking is high and the weathering is in progress. The cluster 3 and the cluster 2 are corresponding to the area where RQD is 0-46%, and the rock class is CL-CM class, and in Table 1 the P-wave velocity is comparatively high, and the S-wave velocity is comparatively low in the cluster 3. A big difference between cluster 3 and 2 is the value of the Electromagnetic-wave velocity. It is thought that the cluster 3 is the area where the permeability is low though the cracking of the rock progresses slightly because the Electromagnetic-wave velocity is low, and the cluster 2 is the area where the cracking of the rock progresses less than the cluster 3, though the permeability is high because the Electromagnetic-wave velocity is high. The cluster 1 is corresponding to the area where RQD is 10-26%, and the rock class is CM class, and Table 1 shows the P-wave velocity and the S-wave velocity are high, and the electromagnetic-wave velocity and the resistivity are comparatively low. Therefore, it is thought that the cluster 1 is the area where the permeability is relatively high, or there are the bleeding channel and a saturated condition below the underground water level.



(a) P-wave velocity

(b) S-wave velocity

(c) Electromagnetic wave velocity

(d) Resistivity

(e)Cluster distribution on the SOM map by k-means method

Figure 9. Cluster boundary and distribution of physical value on the SOM map

Table 1. The relative amount of the geophysical value in each cluster

Cluster	V_p	V_s	V_{el}	R
1	●●●	●●	●●	●
2	●●●	●●	●●●	●●●
3	●●	●	●	●●
4	●	●●	●●●	●

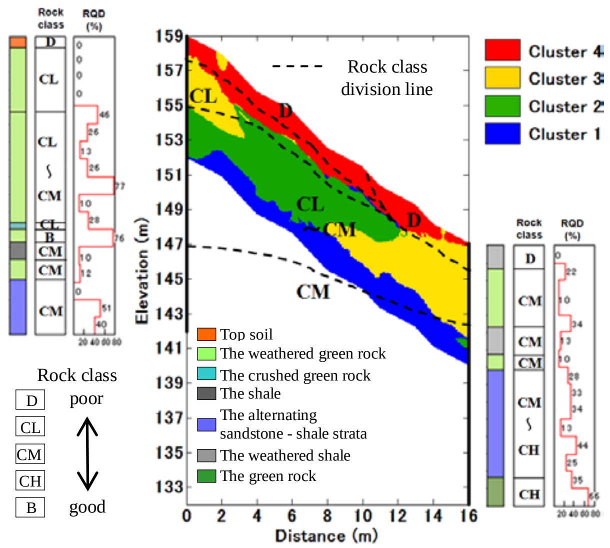


Figure 10. The comparison of the classification result of the fourth times (winter 2009) and the boring investigation in B-district

6 CONCLUSION

In this research, the geophysical data was characterized and classified to 4 clusters by SOM with k-means method. The opinions obtained from this research are shown as follows.

By using different dimensional geophysical value (the P-wave velocity, the S-wave velocity, the electromagnetic-wave velocity, and the resistivity) that had been obtained from various geophysical explorations, we could cluster them by SOM with k-means method and the classification result that was qualitatively corresponding to the degree of the rock class and RQD by the boring investigation

It is recognized that this technique is effective for the improvement of the interpretative accuracy of the compound evaluation of many geophysical explorations because it is possible to read many geophysical exploration data simultaneously and quickly understand and evaluate the feature of each clusters on the SOM map.

In the change with the passage of time of each geophysical data by the regular measurement, it is thought that using the SOM with k-means method makes it possible to evaluate the change of situation of inside of the ground such as the weathering and the aquifer situation.

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