Inverse analysis of turbidity current by deep-learning neural network: application to outcrops

Inverse analysis of turbidity current by deep learning: application to outcrop data

*成瀬 元[1]、福田 壮二郎[1]
*Hajime Naruse[1], Sojiro Fukuda[1]

1. 京都大学大学院理学研究科
1. Department of Geology and Mineralogy, Graduate School of Science, Kyoto University

This study aims to propose a method to estimate paleo-hydraulic conditions of turbidity currents from ancient turbidites by using machine-learning technique. In this method, numerical simulation was repeated under various initial conditions, which produces a data set of characteristic features (spatial distribution of grain-size and thickness) of turbidites. Then, this data set of turbidites is used for supervised training of a deep-learning neural network (NN). Quantities of characteristic features of turbidites in the training data set are given to NN as input data, and the estimated initial condition (e.g. initial flow height, concentration, etc.) of the turbidity current is obtained from output nodes of the NN. In the traing phase of this method, the output values of the NN are compared with the true conditions. The optimization of weight coefficients of NN is then conducted to reduce root-mean-square of the difference between the true conditions and the output values of NN. If the amounts of the training data set are large enough, this machine learning can produce NN that estimate paleo-hydraulic conditions from data of ancient turbidites. In other words, the empirical relationship with numerical results and the initial conditions is explored in this method, and the discovered relationship is used for inversion of turbidity currents.

We produced a implementation of this methodology, and tested its robustness when it applied to the the outcrop data. The 1D shallow-water equations were employed as the forward model. This model calculates a behavior of a surge-like turbidity current transporting mixed-size sediment, and outputs spatial distribution of volume per unit area of each grain-size class on the uniform slope. After the machine learning finished, independent simulations were conducted 100 times in order to evaluate the performance of NN. As a result of this test, the initial conditions of validation data were successfully reconstructed by NN. To test the robustnes of this reconstruction, we added artificial noises on the input data. Also, the subsampling of input data was conducted for examining the stability of the reconstructed values using incomplete data set. As a result, it was revealed that the output values were quite stable even when 10% random values were added to the input data. Also, the precise values were reconstructed subsampled data set that was reduced to 1% from numbers of original data set. We also applied our methodology to the outcrop data of the turbidite bed in the Otadai Formation, the Kazusa Group distributed in Boso Peninsula, Japan. The initial flow conditions of turbudity currents were estimated to be 1.5 vol.% and the slope was 0.01%. The adequacy of this reconstruction will be examined in future studies.

Comparing to previous inverse modeling of turbidity currents, our methodology is superior especially in the efficiency of computation. Existing inverse models use some non-linear optimization methods for estimating initial parameters, which requires numerous repetition of a forward model. On the other hand, NN can estimate initial conditions instantaneously. Although the machine learning procedures take time (several days), this calculation can be easily parallelized. Also, our methodology has advantage in extensibility and applicability to various sediment transport processes such as pyroclastic flows or debris flows.

キーワード：machine learning、sedimentology、turbidite
Keywords: machine learning, sedimentology, turbidite