Tsunami Source Estimation and Waveform Forecasting using Computational Intelligence

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1. Introduction

On the event of the 2011 off the Pacific coast of Tohoku Earthquake, the more precise tsunami wave forecast was issued than the initial one based on an inverse analysis of offshore tsunami motions. This raises attention on the inversion method using tsunami waveform. This analysis is based on only well-known quantities such as the propagation speed of tsunami waves in the homogeneous water and the bathymetry. Thus, this method is expected to be an alternative tool for the conventional one using seismic waves of which propagation speed is affected by the heterogeneity in crustal and upper mantle structures.

This study proposed novel approaches for two subject; estimating the initial tsunami source and forecasting of tsunami waveforms using computational intelligence. The proposed method for the first subject is expected to replace the existing computational methods in revealing the underlying physics on tsunami source movements. The proposed method for the second subject can contribute the development for the real time tsunami forecasting system using offshore tsunami observation data.

2. Results and Discussions

In tsunami waveform inversion using the conventional Green’s function technique, an optimal solution is sometimes difficult to obtain because of various factors. This study proposes a new method to optimize the unknown parameters and introduces computational intelligence to tsunami waveform inversion. This study aims to enhance the traditional least square inversion using two different techniques. Here, a genetic algorithm combined with a pattern search method is used in the first subject, and an extreme learning machine is used in the second subject.

Estimation of tsunami source is conducted to find a suitable distribution of unit source locations and optimal least square parameters prior to the inversion. The method has been tested using an artificial tsunami source and real tsunami case of the 2011 Tohoku event. Unlike the conventional method characterized by equidistant unit sources, the proposed method generates random and scattered unit sources inside the inversion region. This leads to a better approximation of the initial tsunami profile and to significant reduction of the number of parameters, and also to suppression of the negative effect of regularization schemes. The stochastic approach for deriving the time delays is a more flexible strategy for simulating actual phenomena that occur in nature.

In the second subject, this study proposes a new method applying extreme learning machine technique to provide rapid forecasts of tsunami waveforms in coastal areas. The hindcasting analysis is conducted for the 2011 Tohoku tsunami event using the water surface fluctuation data actually recorded at specific locations. The remarkable training speed of the algorithm means that it can run in real-time, therefore applicable to an early warning system. Additionally, the proposed method can capture nonlinearities exhibited by the tsunami.

3. Conclusions

The present method utilizing computational intelligence has successfully enhanced the standard least squares inversion in both subjects of estimating the tsunami source and forecasting the tsunami waveforms.

In the first subject, the proposed method has improved the ability to reveal the underlying physics associated with the tsunami generating processes. In the second subject, the proposed method is found to provide more accurate results without significant increase of the computing time compared with the standard waveform inversion method.