A New System to Validate Algorithms for Early Earthquake Detection

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1. Introduction

The Railway Technical Research Institute has developed algorithms for estimating an earthquake's elements (hypocenter, magnitude, etc.) using the initial tremor of its seismic wave, and for automatically distinguishing between seismic waves and noise (such as the noise of ground vibrations caused by a running train, or electromagnetic noise). Future plans may call for the replacement of existing trackside seismographs with new ones that are based on these new algorithms. But first, it would be necessary to validate application of the new algorithms for the early detection of earthquakes, using data on earthquakes and noises previously obtained from existing seismographs. We therefore developed a new system that permits the efficient validation of the new algorithms with huge volumes of data.

2. System development background

Many different types of seismographs are installed along railway lines. When different types of seismographs store waveform data in different formats, it is impossible to process the data of all those seismographs using the same method. We therefore devised a unified format of standard text type ("JR format") for the data format. We then developed (i) "DataStation," a tool for converting differently formatted seismographic data into data in the JR format, and (ii) "DataCraft," a system to efficiently analyze large volumes of waveform data. During the recent study, we developed a new algorithm for the early detection of earthquakes in DataCraft.

3. System application example: Distinguishing between an earthquake and noise

As an example for application of the new verification system, we conducted tests aimed at distinguishing between an earthquake and train-induced ground vibrations. For the tests we used about 520 items of seismic data previously obtained at government-maintained observation points, and about 600 items of data on train-induced ground vibrations (noises) recorded by trackside seismographs.

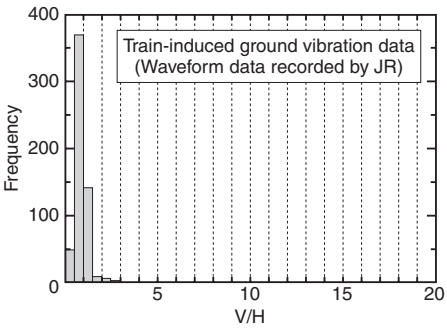

Figure 1. V/H frequency distribution obtained from data on train-induced ground vibrations

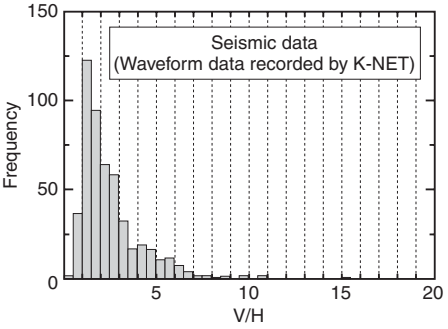

Figure 2. V/H frequency distribution obtained from seismic data during 2 seconds of initial tremors

3.1 Identification by V/H

Seismic waves propagate almost vertically from the hypocenter to observation points, whereas train-induced ground vibrations propagate horizontally from the track. Thus, it is possible to roughly distinguish between seismic vibrations and train-induced ground vibrations using the difference in V/H, that is, the ratio of the maximum amplitude of the vertical component (V) to the maximum amplitude of the horizontal component (H). Fig. 1 shows a V/H frequency distribution obtained from data on train-induced ground vibrations, while Fig. 2 shows the distribution obtained from earthquake data. The figures indicate that if a vibration whose V/H is less than 1.5 can always be identified as a noise, it is safe to judge that 97% of noise data represents noise.

3.2 Identification by increase rate B

Increase rate B, which was devised while developing the new algorithm for early earthquake detection, is an indicator for the rate of increase in the amplitude of initial P-waves. The higher the increase rate B, the more rapidly the P-waves increase. Generally speaking, a high increase rate B indicates that the hypocenter (epicenter) is close to the observation point. Fig. 3 shows the relationship between increase rate B and the true distance to the epicenters of actual earthquakes. According to the figure, increase rate B in earthquakes varies widely from 0.01 to about 100. On the other hand, it was found that in more than 90% of train-induced ground vibrations, the calculated value of increase rate B was less than 0.3. Thus, we consider that when B is less than a certain value (e.g., 0.3), the vibration can be judged as a train-induced vibration (noise).

4. Conclusion

In the future, more and more existing seismographs will be replaced with new ones capable of earlier earthquake detection. It is expected that our new system will be employed to validate the application of our new algorithm for the early detection of earthquakes.

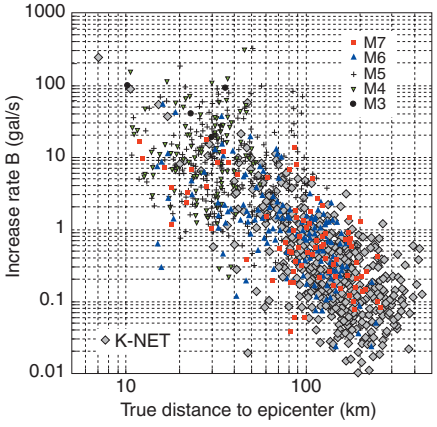

Figure 3. Relationship between increase rate B during 2 seconds of initial tremors and the true distance to epicenter