Calculating Rotational Ground Motions by Finite Difference Method

Dong-qing Li, Yun Wang, Li-xia Sun

China University of Geosciences (Beijing)

The ground motions caused by earthquakes include not only translational ground motions, but also rotational ground motions(Lee et al,2009). At present, there are two methods to obtain the rotational ground motions. One is to compute the components of rotation with the recording translation indirectly(e.g., Spudich et al.,1995; Huang,2003; Spudich and Fletcher,2008), the other is to record the components of rotation directly by rotational sensors(e.g.,Nigbor,1994; Takeo, 1998; Huang et al.,2006). The methods used to calculate the rotational motions by translational components include finite difference methods and the travelling-wave method mainly, among which the finite difference method is simpler and easier to be realized.

The finite difference methods include two-point finite difference method and three-point finite difference method(Sun et al,2018). The two-point finite difference method is used to compute the horizontal components of rotation, and the three-point finite difference method is used to compute the vertical components of rotation. In this study, the six-component dense array data activated with an explosive source in March 2008 in Taiwan(Lin et al., 2009) are used. We compared the waveforms and spectra of the first arrival by finite difference methods with the recording array data. We are going to determine whether the finite difference methods can be used as effective and alternative methods to calculate the rotational components within allowed error. In addition, we test a new finite difference method in this study. The original two-point finite difference method for computing horizontal components of rotation is upgraded to a four-point difference grid. By increasing the number of stations and utilizing more array data, we want to study whether it can improve calculating accuracy of the difference methods.

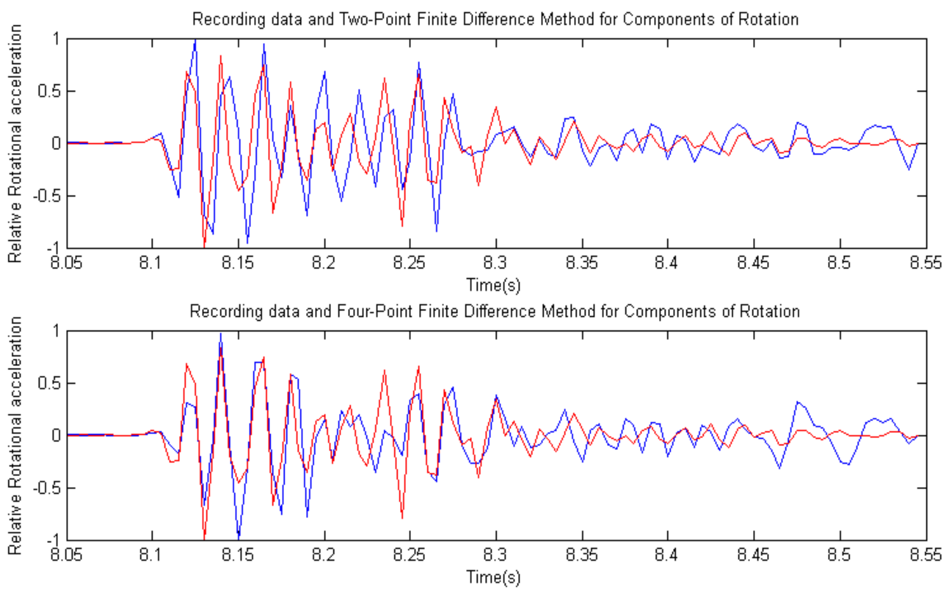

Fig. 1 Time-domain waveform comparison of two-point finite difference method and four-point finite difference method (where the red curves represent real recording data)

We compared the Rxs computed with the two-point finite difference method and the four-point finite difference method. By comparing the time-domain waveforms of the two-point finite difference method with the four-point finite difference method, it can be found that the four-point finite difference method is better than the two-point finite difference method, when comparing the recording data. For time-domain waveform, the correlation coefficient between the waveform computed by two-point difference method and recording data is 0.5779, while that computed by four-point difference method and recording data is 0.72.

Further, the amplitude spectrum comparisons are considered, as illustrated in Fig. 2.

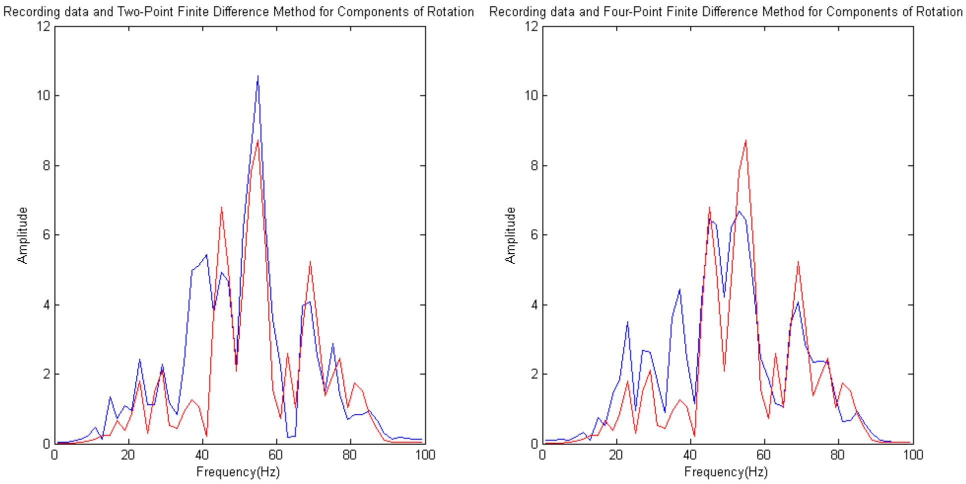

Fig. 2 Amplitude spectra comparison of two-point finite difference method and four-point finite difference method (where the red curves represent real recording data)

From the amplitude spectrum, it is found that the four-point finite difference method is more consistent with the recording data on the whole, especially in the high frequency of 43Hz, which is the prominent frequency of the rotational sensors(Lin et al, 2009). Because of an explosive source employed, in the high frequencies, the four-point finite difference method shows more consistent with the recording components of rotation than the two-point finite difference method. With respect to the amplitude spectrum, the correlation coefficient between amplitude computed by the two-point difference method and recording data is 0.8625, while that computed by the four-point difference method and recording data is 0.8829.

Through analyses and comparisons of actual data, we find that, for the improved two-point finite difference method, the accuracy of calculating can be improved by using more recording array data.

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