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A TECHNIQUE FOR QUICK ESTIMATION OF SEISMIC GROUND MOTION DISTRIBUTION FROM OBSERVED SEISMIC INTENSITIES ASSISTED BY PREVIOUSLY CONDUCTED MINUTE SIMULATIONS

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SUMMARY

We propose a simple technique estimating seismic ground motion distribution immediately after an earthquake. The technique bases on two different approaches. One is interpolation of observed values of strong motion data, and another is minute simulation of earthquake ground motion based on modern strong motion seismology.

First, we make strict simulation of seismic ground motion distribution for possible source faults and store the result. This process takes much computation time especially we introduce three dimensional wave propagation. However, fortunately we have enough time before the severe earthquake hits the target area. Secondly, we obtain observed strong motion data, i.e. maximum values or seismic intensities, just after the earthquake. Next, system searches most approved simulation result from the previously conducted stocks. Then, we obtain differences between the observed and the simulated values at sites, and make a mathematical model of spatial distribution from the discrepancies. We use Spline functions here. Finally, we modify the previously simulated distribution of ground motion adding the correction values derived from the discrepancy model. The estimation is done within several seconds after receiving observed data. The stocked simulations are also useful for disaster prevention planning as an earthquake scenario. And once severe earthquake hits the area, the scenario is immediately revised based on observed data by the technique described above.

Applying the technique to the 1995 Hyogo-ken Nanbu, Japan Earthquake as a post prediction, we can get brief figure of strong ground motion distribution including high intensity zone that appeared in Kobe City. We consider that the technique has enough quality to estimate strong ground motion distributions in the area where characteristics of possible source faults have been well determined. We also expect that the concept of storing minute strong motion simulation results from expecting seismic fault is rational approach for quick estimation.

INTRODUCTION

Several techniques to estimate seismic intensity distribution immediately after the severe earthquake have been proposed to contribute quick disaster estimation. We consider that the methods can be classified into two groups.

One is interpolation of observed values and the other is calculation based on empirical attenuation formula. As for the first method, we need a lot of seismometers in the target area to obtain sufficiently accurate interpolation. Further more, we could not detect a high amplitude zone from neighboring low amplitude observation values, using a simple interpolation technique. For the second case, simple attenuation formulae are generally used to conduct quick estimation from magnitude, distance, and site condition information. However, strong motion distribution is strongly affected by source rupture process, especially in the vicinity of the fault. We are afraid

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that over simplified estimation of strong motion will mislead following disaster evaluation. On the other hand, detailed strong motion simulation requires much time and a lot of parameters to be assumed.

Avoiding disadvantage of those two streams, we propose a simple technique that combines preliminary conducted minute strong motion simulation and immediately obtained observed data. The advantages of the proposing technique is that minute enough strong motion distribution is able to be estimated immediately after observing seismic intensities.

DISCRIPTION OF PROPOSING TECHNIQUE

Here we describe our proposing technique. The basic flow of the technique is shown in Figure 1. Once severe earthquake occurs, there is not enough time to make detail simulation of strong ground motion. However, before the earthquake we might have a lot of time to prepare the event. Our proposing technique efficiently uses this free time before the severe earthquake hits the target area.

As first, minute simulation of strong ground motion distribution for several possible source faults are conducted and store the results. The simulations are expected to base on modern seismology that includes fault rupture processes and response of sedimentary structures. The estimations have to be done considering different rupture processes, i.e. rupture starting point and asperity for each target fault system. This simulation process takes much computation time and computer memory especially we introduce three dimensional wave propagation. However, an additional advantage of our method is that these preliminary conducted simulations are easily used as for a scenario earthquake for disaster prevention plans. Applying the method, we have to know the enough information of target earthquake faults to model the fault rupture process.

Secondly, we have to obtain observed strong motion data immediately after the earthquake. For the observed value, maximum values (velocity or acceleration) or seismic intensities are expected. The method does not needs wave traces to be ready to calculation quickly. We need properly spread strong motion observation points applying the technique. However, they are not required so much dense. In the Kobe and Osaka area, we will show that the distance between the sites is enough as 20km.

After receiving the observed values, the system searches the most approved simulation result from the previously conducted stocks. It calculates differences between the observed and the simulated values at sites. Comparing the error deviation between simulation and observation, the system selects the most approved one. In this stage, earthquake source information is not required. However, the accuracy to select the proper result might be getting better with source information. The system makes a mathematical model of spatial distribution from the discrepancies between simulated and observed values. Here we apply Spline functions after Koketsu and Higashi (1992) modeled bedrock structure with 3-D 2nd order B-Splines.

Finally, the previously simulated distribution of ground motion is modified adding the correction values derived

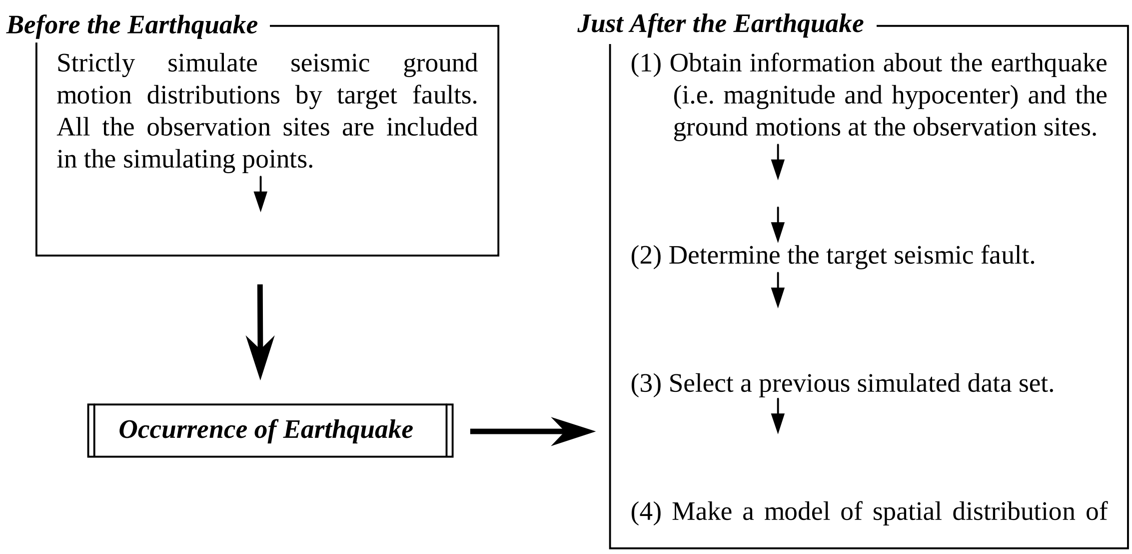

Figure 1. Flow chart of proposing method.

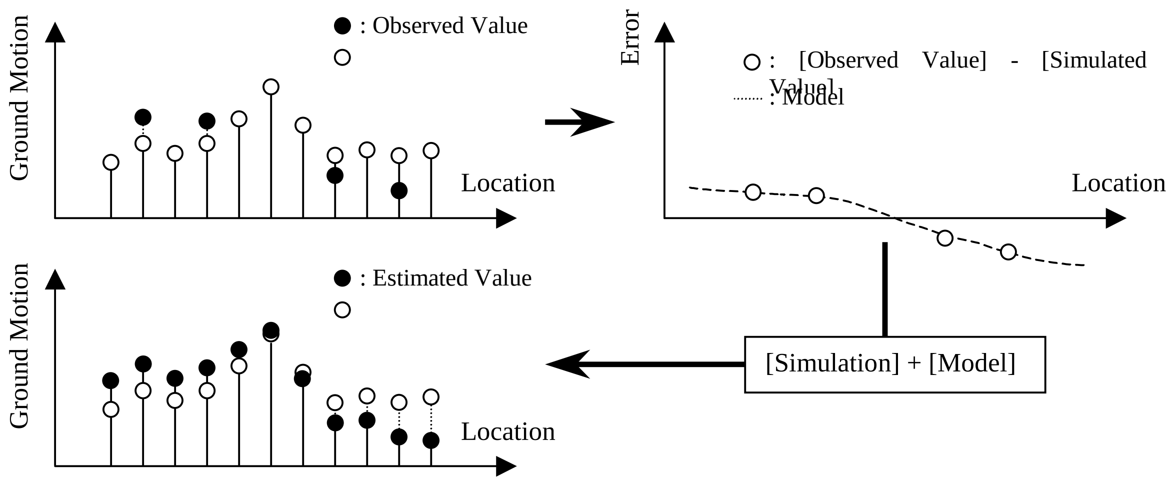

Figure 2. Image of proposing method. This figure is described along an analyzing line for easy understanding, but actual operations are done for target plane.

from the Spline function model on the simulated values. The concept of the process above is shown in Figure 2. In the real analyzing process, the calculation is done on meshes in a two dimensional plane that cover target area. However, the figure is described along an analyzing line for convenience of understanding the method. The analysis will be done within several seconds after receiving observed values. We consider that it is quick enough and that the result is accurate enough. Again our concept is that the scenario earthquake simulation shall be revised quickly based on observed value, once severe earthquake hits the target area.

TEST CALCULATIONS

Here we make brief test calculations using seismic intensity distributions derived from theoretical strong motion simulation method. The method is based on Green's function summation method, i.e. Irikura (1986). Instead of empirical Green's functions, stochastic Green's functions after Boore (1983) is employed. To calculate stochastic Green's function for each subfault, frequency dependent radiation pattern is considered after Kamae and Irikura (1992). We also introduce site response calculating Haskell's matrix of SH and P-SV wavefields [Haskell (1953)] respectively for a horizontally layered structure derived from a basin structure model [Miyakoshi et al. (1997)] at each calculation point. For the calculation point, three component acceleration traces are calculated and JMA seismic intensity is calculated from them. The simulation method used in this paper can explain minute fault rupture effect and basic site response. This is useful to obtain natural seismic intensity distributions.

We assume a fault system shown in Figure 3. The fault is almost same as the 1995 Hyogo-ken Nanbu Earthquake. We make two simulations based on fault rupture process. For case 1, the rupture starting point is set at the center of assumed fault and the rupture propagates uniformly and smoothly. As case 2, we assume the rupture starting point beneath the Akashi Channel and we set an asperity at the center of the fault. In both cases, total seismic moment releases are same. Figure 4 shows a result of the rupture case 1. It is clear that the strong motion distribution is almost same as theoretical radiation pattern and is affected by site conditions. In the Kobe City area, maximum JMA seismic intensities are estimated as 6 low. This simulation result is stocked as for a previously conducted one. The result of the rupture process case 2 is shown in Figure 5. In this case maximum seismic intensity is 6 high. In the 1995 Hyogo-ken Nanbu Earthquake, JMA intensity 7 area appeared in and around the Kobe City. However, these simulations can not explain this phenomenon. It may be caused that we do not consider surface soft layers and basin edge effect. Also the fault model is different from the one of the 1995 Hyogo-ken Nanbu Earthquake. We assume the simulation of Figure 5 as an actually occurred earthquake, so called target earthquake.

As shown in Figure 6, we put imaginary sites inside the target area. The locations of sites are same as national strong motion observation network in Japan (K-net) [Kinoshita et al. (1998)]. Additionally, we assume three imaginary ocean bottom seismometers in the Osaka Bay. At these imaginary sites, seismic intensity by actually occurred earthquake (Figure 5) is immediately obtained and sent to observation center. The observed seismic intensity is compared with previous simulation result (Figure 4) at each point. The previously simulated

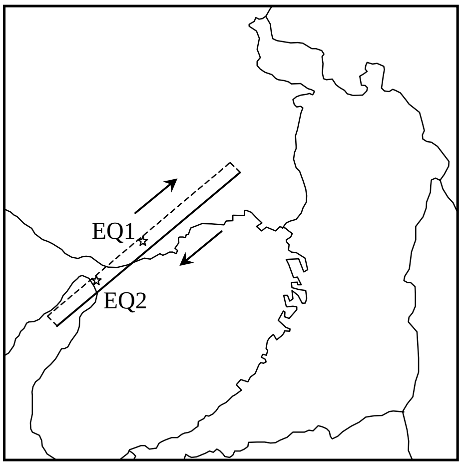

Figure 3. Assumed fault (Rokko-Awaji Fault System). The fault is the same that caused the 1995 Hyogo-ken Nanbu Earthquake.

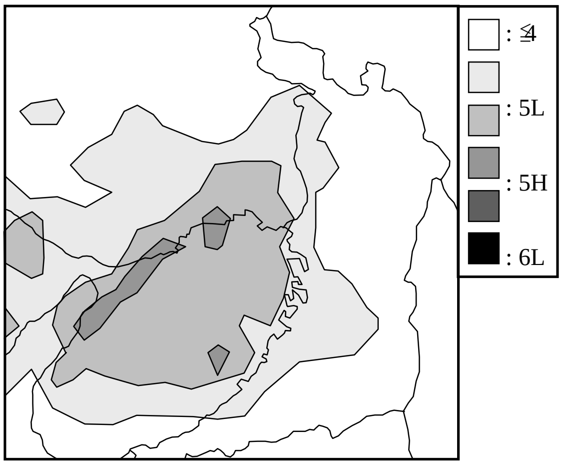

Figure 4. JMA seismic intensity distribution in case that uniform rupture started from the center of the fault (EQ1). This is used as a previous simulation stock.

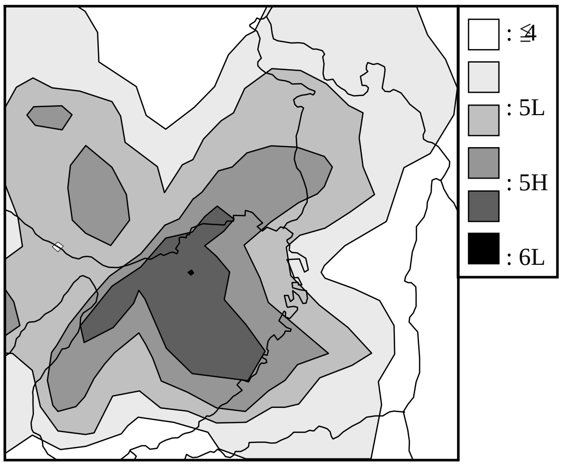

Figure 5. Same as Figure 4, but for the case that irregular rupture started from the Akashi Channel with an asperity in the center of the fault (EQ2). This is used as an actually occurred hazard.

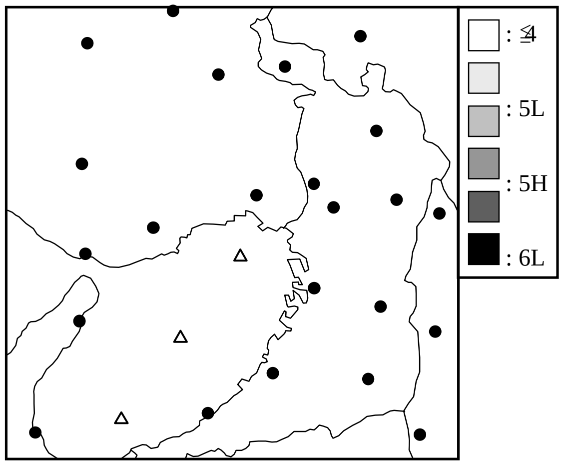

Figure 6. Assumed observation points. From these points, seismic intensities are reported immediately after the earthquake. The locations are same as national strong motion observation network in Japan (K-net;●) with three imaginary ocean bottom seismometers (△).

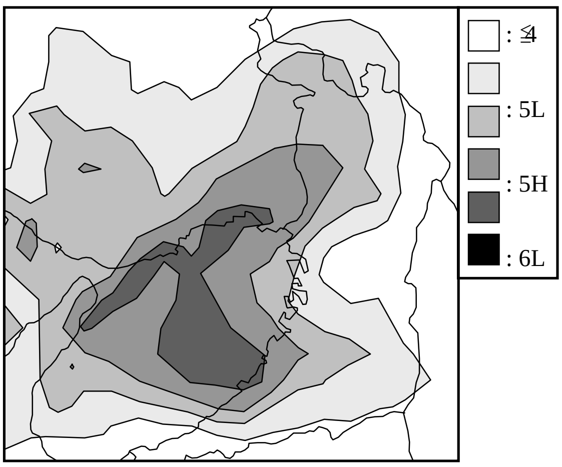

Figure 7. JMA seismic intensity distribution estimated from Figure 4 by using the proposing technique. The observed seismic intensity obtained at the sites in Figure 6 are used.

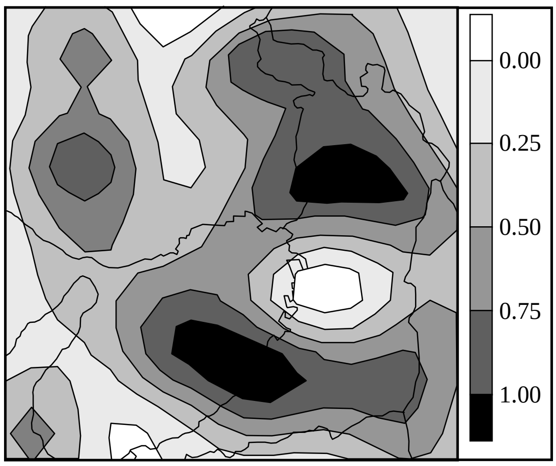

Figure 8. A model of spatial distribution obtained from the discrepancies between previously simulated values and observed values. This is used to create the result of Figure 7.

distribution of seismic intensities is modified based on observation values. Finally, we can obtain revised distribution shown in Figure 7. It is clear that the estimation well correspond to the actual distribution, especially in land area. Figure 8 shows the distribution of discrepancies between observed and preliminary simulated values. From the figure, we can notice that the revision has made to cover the difference of fault rupture assumptions according to asperity and forward directivity effect.

Next, we apply the technique to actually occurred earthquake. Figure 9 shows the sites where the records by the 1995 Hyogo-ken Nanbu, Japan Earthquake are obtained, i.e. Toki et al. (1995), Nakamura et al. (1996). Those data were published one month or later after the earthquake. However, here we assume that the data were obtained just after the earthquake and our method was applied. From the previously conducted simulation shown in Figure 4 and observed seismic intensities, we can estimate the distribution of strong ground motion. Figure 10 shows the result. We can see JMA seismic intensity 7 area in the Kobe City and JMA intensity 6 high is widely spread along the fault rupture area. The result briefly agrees well as the seismic intensity based on minutely investigated distribution from the disaster of the earthquake. From these two test simulations, we can emphasize that the proposing technique has enough potential to apply real earthquakes.

FURTHER PROBLEMS

The proposed method works well in the case that potential faults are well detected, i.e. Kobe, Osaka, Kyoto area, Japan; San Andreas fault zone, USA; Northern Anatorian fault zone, Turkey, and so on. However, the method has disadvantage in case that an earthquake occurs from an unexpected fault. We consider this is one of further problems of our proposing method. We have to prepare reasonable alternatives for the case.

Using the proposing method, we van modify the preliminary simulated seismic intensity distribution to fit the actually occurred earthquake. These modifications are required mainly because of improper setting of fault rupture model between previous simulation and real earthquake. We assume that site response itself does not change so much at any sites in our proposing technique. Here, we conduct a simple simulation for all target sites, assuming the common fault exists beneath each site. Figure 11 shows the image of concept. In this simulation, fault condition is same for all calculation points, but site response is different for each site. We stock these results for the case that earthquake will happen on the unexpected fault. Applying the process above, seismic intensity distribution for proper fault rupture will be briefly modified. Finally, we expect that we can obtain rather good estimation for the actually occurred earthquake.

CONCLUSIONS

We have proposed a simple technique for quick estimation of seismic ground motion distribution. A system

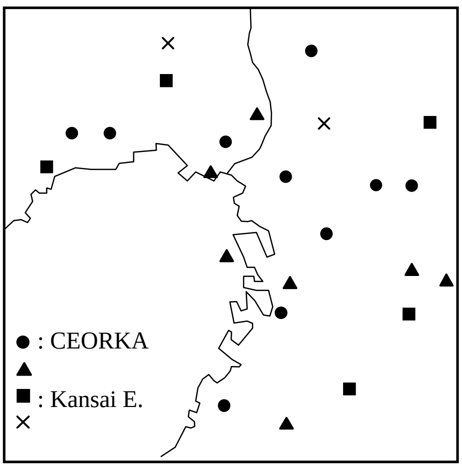

Figure 9. The observation stations where the records from the 1995 Hyogo-ken Nanbu Earthquake are obtained. We assume the case that those records were gathered immediately after the earthquake.

Figure 10. Estimated JMA seismic intensity distribution of the 1995 Hyogo-ken Nanbu Earthquake by the proposing technique. Calculated seismic intensity from observed records at the sites in Figure 9, and previous simulation stock in Figure 4 are used.

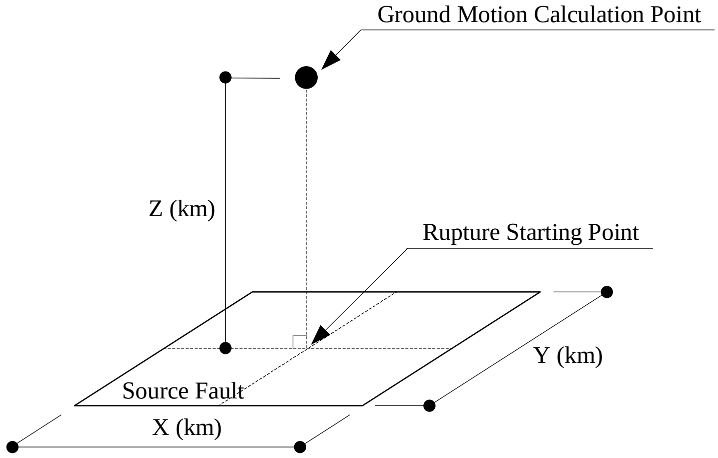

Figure 11. An image to set common source fault beneath the each calculation points. In this case, seismic intensity distribution based on each site response is calculated.

based on our proposal is expected to generate a useful distribution of seismic intensity. And it might be accurate enough to make decision for urgent rescue and following disaster prevention. We have conducted several case studies and found that the technique is applicable for the really occurred large earthquake hazard, i.e. the 1995 Hyogo-ken Nanbu, Japan Earthquake. In our proposal, minute strong motion simulation results are required. They are also useful for previous hazard and disaster estimation as earthquake scenario. We consider that this kind of stocks must be prepared for all areas where earthquake possibilities exist. Our technique also requires strong motion seismographs that can broadcast strong motion information immediately after the event. We consider this type of sensor should be set where earthquake possibility is high. As a result, our proposed technique is applicable for any condition, if there is previous strong motion simulation result and strong motion seismographs. If the information is prepared enough quantity and quality, we hope we can obtain accurate estimations of seismic hazard distribution. On the other hand, even if such kind of information is little, we can get result with moderate accuracy according to the quality and quantity of information. We hope that the proposed technique will contribute to take measures in the initial stages for mitigating seismic disaster just after a severe earthquake hits populated area.

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