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Simulation of ground motion records by consideration of spectral acceleration correlation

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ABSTRACT

Most of the reliable Ground Motion Record (GMR) simulation procedures use a seismological model including source, path and site characteristics. However the response spectrum of the simulated GMRs is different in some aspects when is compared with the response spectrum based on recorded GMRs. The correlation between the spectral values is one of the most important characteristics of a record which can be different for the simulated and recorded GMRs. Since this correlation has a significant influence on the structural response, it is needed to demonstrate the consistency of the simulated ground motions with the recorded ones. This issue has been investigated in this paper. The results show that using a simple point source for modeling of the faulting mechanism leads to a significant difference between the recorded and simulated ground motions in the mentioned issue. However, the use of a finite fault model for the source mechanism can modify this imperfection. Finally, a set of modeling parameters has been obtained in this paper, by using the Genetic Algorithm (GA) as an optimization technique, for more realistic simulation of GMRs.

Keywords: Stochastic method, Simulation, Ground motion, Random vibration, Site amplification.

1. INTRODUCTION

As non-linear dynamic analysis becomes a more frequently used procedure for the seismic evaluation of the structural demand, it is increasingly important to find and use the selected records based on a reasonable mechanism. The ground motion simulation has been considered as an important issue in the earthquake engineering associations [2], since the lack of available real ground motion records [1].

Using the simulated ground motions for the structural analysis purposes is a challengeable subject due to some inconsistency with the realistic recorded ground motions. As a result, the most of engineering codes emphasize on the use of the recorded ground motions instead of the simulated ones. One of these disagreements can be observed in the autocorrelation function of spectral response of simulated and recorded ground motions. This inconsistency which has a significant influence on the structural response has been discussed in this paper and a practical solution is proposed. First, it is needed to present a brief review about some of the well known procedures for ground motion simulation. It is worth to emphasize that only the physical-based stochastic approach is considered in this paper and the other approaches i.e. spectral matching method has not been mentioned.

Stochastic Method SIMulation (SMSIM) is a FORTRAN based program for the stochastic simulation of realistic ground motions which was introduced by David Boore [3]. The Source, path and site effects are three significant terms in the SMSIM which are integrated by using a random vibration framework in order to simulate a realistic earthquake vibration. From the mentioned terms, the source effect is the dominant term which differ SMSIM from the other procedures i.e. Extended Fault SIMulation (EXSIM) presented by Motazedian and Atkinson [4]. The excitation source is considered to be a specified point in the SMSIM program. On the other hand, the fault is divided to some sub-sources in the EXSIM and a point source is assigned to each sub-source [5, 6, and 7]. Point source method cannot consider ground motion key parameters such as long time duration and amplitude dependence on azimuth of stations (directivity effect) in the large earthquakes. To deal with this problem, a modeling approach based on a finite fault has been presented which has strongly been accepted in the past two decades. The modeling approach based on a finite fault combines the aspects of plane source with the ground motion model based on the point source. Stochastic finite fault simulation uses time delay method and the summation of accelerograms corresponding to a two dimensional network of sub faults. The finite fault methodology which is used in EXSIM is more advanced and has further parameters comparing with the other approach and it is expected to describe the faulting mechanism in more realistic way. For an example of a simulated record computed by EXSIM and a real GMR for magnitude equal to 5.7 are shown in Figure (1).

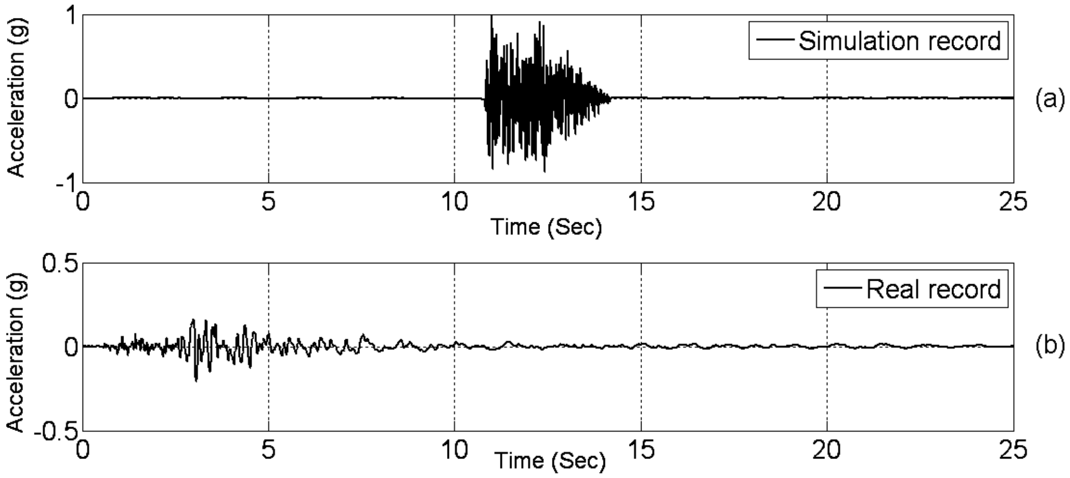

Figure 1: *(a) Simulated ground motion record for the scenario M=5.7, R=4 km; (b) Real ground motion for the scenario M=5.7, R=7.5 km (Coyote Lake 1979).*

The main objective of this paper is to study the consistency of the autocorrelation function of spectral response resulted from the simulated and recorded ground motions. This idea is originated from an independent study completed by Polsak Tothong [8]. In the mentioned study, it is claimed that the autocorrelation function of response spectra for simulated ground motions disagree with the far-filed recorded ground motions.

2. AUTOCORRELATION FUNCTION OF SPECTRAL RESPONSE

The acceleration spectral response autocorrelation function which is computed for a set of GMRs is an indicator of spectral shape. On the other hand, the nonlinear response of structures is controlled by the spectral shape of the considered ground motions. As an obvious result, the inconsistency of simulated and recorded ground motions, as claimed by Tothong [8], can be accounted as a negative effect for the ground motion simulation issue. Figure (2) shows the autocorrelation function of spectral response for a set of ground motion simulated by SMSIM program based on the point source model as well as for a set of recorded ground motions. The inconsistency in the correlation of the simulated and recorded ground motions is clear, as it is mentioned by Tothong [8]. The authors hypothesized that this difference is due to this fact that a simple point source has been used for simulation and it can be modified by application of a finite fault model instead of the point source. This assumption is studied in the following sections. It should be noted that the real GMRs which have been used here, can be found in [9].

3. ADJUSTMENT OF EXSIM TO REALISTIC GROUND MOTIONS

In order to evaluate the above mentioned hypothesis, EXSIM has been used to simulate the consistent ground motions. The structure of EXSIM is based on the finite fault approach and uses 11 parameters for simulation of ground motions. These parameters are shown in Table (1). This table also contains a reasonable range for each of parameters that are introduced in [10]. The main objective is to find an optimum vector from these parameters that causes the most consistency of the simulated and recorded ground motions.

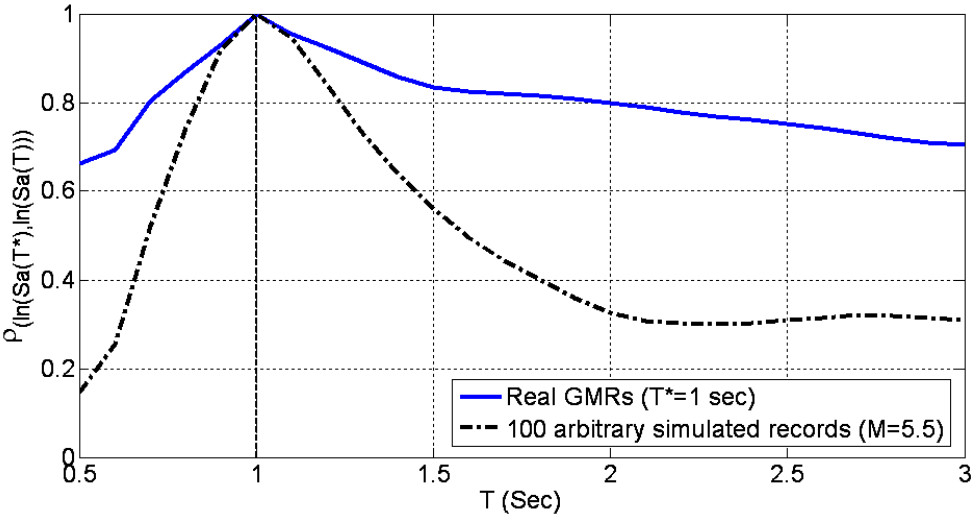

Figure 2: *The acceleration response spectral autocorrelation function for both of EXSIM simulated records and real ground motion records.*

Table 1: *The key Parameters of EXSIM and the corresponding range.*

No	Parameter	Range
1	Stress drop	30~320
2	Kappa	0.002~0.08
3	Fault dip	10~90
4	Dept of fault	1~30
5	Fault length factor	0.2~0.8
6	Fault width factor	0.4~1
7	Stress_ref	30~300
8	Shear-wave velocity (Beta)	2~4
9	Shear-wave density (rho)	1.5~3.5
10	Damping of response spectra	5~10
11	Pulsing area percent	20~90

A significant effort is needed to investigate the effect of these parameters on the spectral acceleration autocorrelation values over a period range. This subject can be considered as an optimization problem to find the best and optimum values for each parameter in its particular range. Then simulated records can be generated based on the obtained optimum parameter values. A suitable tool which was used recently for optimization is the Genetic Algorithm (GA). The concept of the GA was proposed in 1975 at Michigan University by Holland [11] and developed by Golberg [12]. In the optimization problem some variables and a function for minimization should be introduced. In the GA approach the crossover fraction was chosen to be 0.75. This function is a necessary part of the GA and prevents it from converging to local optimum. The mutation function was selected to be as the Gaussian mutation function. In order to set up an appropriate optimization procedure, the adjustment of the autocorrelation function between the simulated and the recorded ground motions has been selected as the target function. The resulted optimized parameters are indicated in Table (2) and the autocorrelation function of the EXSIM simulated ground motions is shown in Figure (3). As the last figure shows, a good agreement between the recorded and the simulated ground motions is obtained. Figure (4) shows the mean acceleration response spectra for the recorded ground motion set and also for a set of simulated ground motions. The resulted compatibility is another evidence for verification of this study.

4. RESULTS AND CONCLUSIONS

Using the simulated ground motions for the structural analysis cannot be accounted as a valid approach if any significant disagreement exists between the simulated and the recorded ground motions. When employing the point source approach for simulation procedure, a dramatic inconsistency on the response spectra autocorrelation function of the simulated and the recorded ground motions is occurred. In this paper, a calibrated finite fault model has been proposed that removes the mentioned inconsistency. This model can be used for ground motion simulation purposes.

Table 2: *The optimum values for 11 EXSIM key parameters.*

Parameters	Optimum value
Stress drop	252
Kappa	0.08
Fault dip	34.5
Dept of fault	5.80
Fault length factor	0.34
Fault width factor	0.68
Stress reference	149.5
Shear-wave velocity (Beta)	3.23
Shear-wave density (Rho)	2.15
Damping of response spectra	5.86
Pulsing area percent	64.47

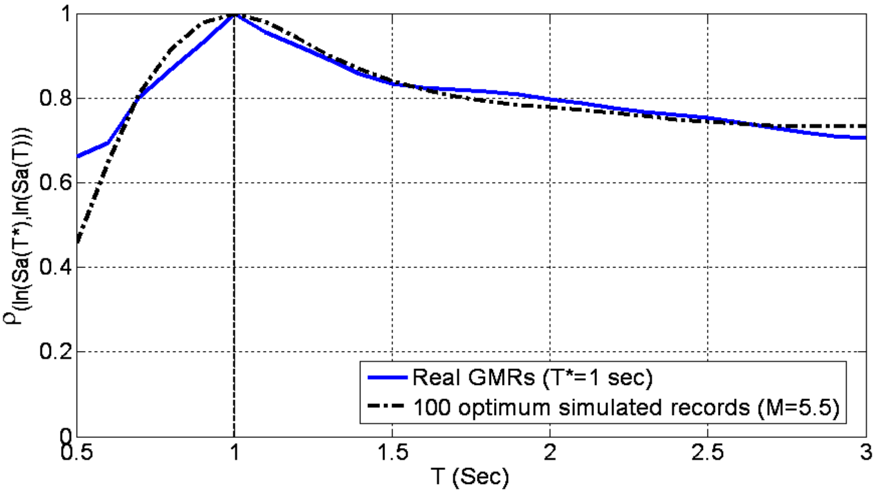

Figure 3: *The spectral acceleration response autocorrelation function for both of the EXSIM simulated records and the real ground motion records.*

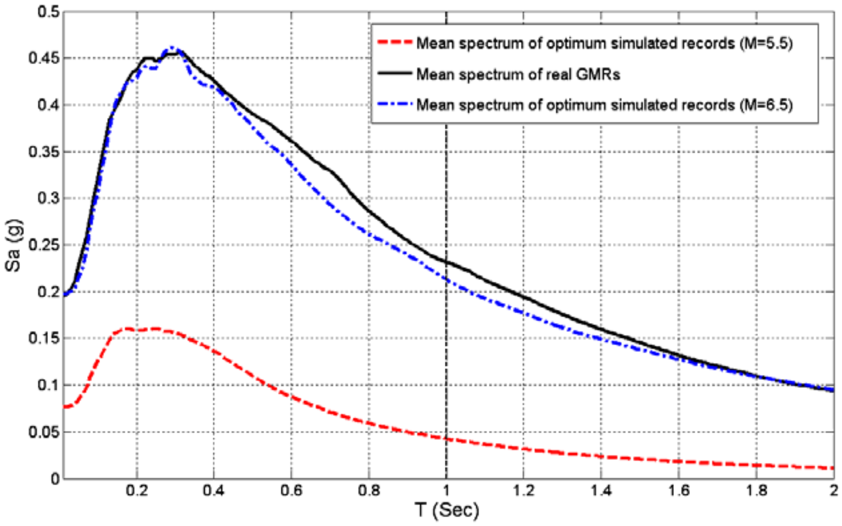

Figure 4: *The acceleration response spectra resulted from the EXSIM simulated ground motions and the real ground motion records (T*=1 (sec)).*

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