EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS, VOL. 20, 803–804 (1991)

SHORT COMMUNICATIONS

DISCUSSION ON A PAPER BY E. REINOSO, M. ORDAZ AND F. J. SANCHEZ-SESMA[1]

MIHAILO D. TRIFUNAC

Department of Civil Engineering, University of Southern California, Los Angeles, CA 90089-2531, U.S.A.

The paper by Reinoso *et al.*[1] proposes an algorithm for the fast estimation of response spectra. Their approach uses the results of Cartwright and Longuet-Higgins[2] for estimation of the expected peak amplitudes of a random process with Rayleigh distribution of extrema. The authors indicate that their algorithm is about 150 times faster than the exact computations. The absolute error of their spectral estimates is in the range from about 5 to 30 per cent.

The present discussion is motivated by: (1) the appearance of misleading statements, (2) the surprising lack of references to earlier and current relevant work and (3) the presentation of a method which is almost identical to the one published some fifteen years ago.

The authors use the definition of the duration of strong ground motion, T_s, which, to quote from their paper 'is the duration of Trifunac and Brady which is defined in terms of the Arias intensity of the signal'. This statement is not correct. The duration of strong motion as defined in our paper[3] uses the integrals of the form $\int_0^T f^2(t)\mathrm{d}t$. $f(t)$ represents absolute acceleration of ground motion if the above integral is to be used to estimate the work per unit mass done by the inertial force acting on all single-degree-of-freedom viciously damped oscillators, during $0 \leqslant t \leqslant T$, where T is the duration of the strong motion record. Only in this case our definition uses the functional which is analogous to the Measure of Earthquake Intensity (as defined by Arias[4]), but it is not defined in terms of it. $f(t)$ becomes $v(t)$ (ground velocity) if one wishes to calculate the estimates of radiated seismic energy (i.e. our definition of duration represents that time during which say 90 per cent of radiated seismic energy passes by the recording station). $f(t)$ corresponds to acceleration $a(t)$, velocity $v(t)$, or displacement, $d(t)$, of ground motion when one wishes to estimate the peaks of ground motion $a_{\max}$, $v_{\max}$ and $d_{\max}$. Through Parseval's theorem, the above integrals can also be related to the integrals of response spectra (Udwadia and Trifunac[5,6]), which have been used to define the spectral intensity of earthquakes (Housner[7]).

The omission of any reference to the work of Udwadia and Trifunac[6] is particularly serious. In this paper Udwadia and Trifunac show how the response spectra can be computed from the Fourier amplitude spectra of strong ground motion, using essentially identical approach as in Reinoso *et al.*[1] and present examples which include the expected peak response amplitudes, the most probable peak amplitudes and the 90 per cent confidence intervals for the peak estimates. Udwadia and Trifunac also consider ε, the 'width' of the Fourier amplitude spectrum, and suggest the range between 0·2 and 0·5 for typical calculations. In the work of Reinoso *et al.* ε is neglected (i.e. $\varepsilon = 0$). It is interesting to note that the work of Udwadia and Trifunac[6] has been referenced by Trifunac and Brady[3] and again in the more recent work dealing with further refinements and generalizations of the probability distributions of peak amplitudes (e.g. Amini and Trifunac[8]; Gupta and Trifunac[9,10]).

Finally, it is not clear how to interpret the authors statement that their proposed algorithm is 'about 150 times faster than the exact one', since it is not indicated which exact algorithm is in fact used. Recently, there has been much progress in the fast algorithms for computation of response spectral amplitudes (e.g. Lee[11,12]) and the speed of computations has increased so much, that the repetitive computation of response spectra, which indeed used to be a laborious and time consuming operation, is no longer a problem.

REFERENCES

1. E. Reinoso, M. Ordaz and F. J. Sanchez-Sesma, 'A note on the fast computation of response spectra estimates', *Earthquake eng. struct. dyn.* **19**, 971–976 (1990).
2. D. W. Cartwright, and M. S. Longuet-Higgins, 'The statistical distribution of maxima of a random function', *Proc. roy. soc. London.* **A237**, 212–232 (1956).
3. M. D. Trifunac and A. G. Brady, 'A study on the duration of strong earthquake ground motion', *Bull. seism. soc. Am.* **65**, 581–626 (1975).
4. A. Arias, 'A measure of earthquake intensity', in *Seismic Design of Nuclear Power Plants* (Ed. R. Hansen). Massachusetts Institute of Technology, Press, 1970.
5. F. E. Udwadia and M. D. Trifunac, 'Damped fourier spectrum and response spectra', *Bull. seism. soc. Am.* **63**, 1775–1783 (1973).
6. F. E. Udwadia and M. D. Trifunac, 'Characterization of response spectra through the statistics of oscillator response', *Bull. seism. soc. Am.* **64**, 205–219 (1974).
7. G. W. Housner, 'Intensity of ground motion during strong earthquakes', California Institute of Technology, Earthquake Engineering Research Laboratory, Pasadena, California, 1952.
8. A. Amini, and M. D. Trifunac, 'Distribution of peaks in linear response', *J. eng. mech. div. ASCE* **107**, 207–227 (1981).
9. I. D. Gupta and M. D. Trifunac, 'Order statistics of peaks in earthquake response', *J. eng. mech. ASCE* **114**, 1605–1627 (1988).
10. I. D. Gupta and M. D. Trifunac, 'Probabilistic spectrum superposition for response analysis including the effects of soil–structure interaction, *J. probabilistic eng. mech.* **5**, No. 1, 9–18 (1990).
11. V. W. Lee, 'A new fast algorithm for the calculation of response of a single-degree-of-freedom system to arbitrary load in time', *Soil dyn. earthquake eng.* **3**, 191–199 (1984).
12. V. W. Lee, 'Efficient algorithm for computing displacement, velocity and acceleration responses of an oscillator to arbitrary ground motion', *Soil dyn. earthquake eng.* (in press).

REPLY BY AUTHORS TO M. D. TRIFUNAC

EDUARDO REINOSO

Centro de Investigación Sísmica, Fundación Javier Barros Sierra, Carretera al Ajusco 203, Tlalpan 14200, México, D.F., Mexico

AND

MARIO ORDAZ AND FRANCISCO J. SANCHEZ-SESMA

Centro de Investigación Sísmica and Instituto de Ingeniería, Ciudad Universitaria, Apdo. 70-472, Coyoacán 04510, Mexico, D. F., Mexico

We agree with, and thank, Professor Trifunac for his comments regarding our use[1] of the duration of strong ground motion, T. We should have read Udwadia and Trifunac[2] in greater detail. Had we done this, our note would have been entitled 'New evidence to support Udwadia and Trifunac's algorithm'. Indeed, our approach is very similar to the one published nearly 17 years ago. The speed of the algorithm is about 150 times faster than Newmark's β-method.

REFERENCES

1. E. Reinoso, M. Ordaz and F. J. Sanchez-Sesma, 'A note on the fast computation of earthquake response spectra estimates', *Earthquake eng. struct. dyn.* **19**, 971–976 (1990).
2. F. E. Udwadia and M. D. Trifunac, 'Characterization of response spectra through the statistics of oscillator response', *Bull. seism. soc. Am.* **64**, 205–219 (1974).