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A STOCHASTIC APPROACH TO SYNTHESIZING RESPONSE SPECTRUM COMPATIBLE SEISMIC ACCELEROGRAMS

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ABSTRACT

Regulatory agencies require the use of artificial accelerograms satisfying specific criteria of compatibility with a given design spectrum, as input for certain types of analyses for the aseismic design of critical facilities. Most of the numerical methods for simulating seismic motions compatible with a specified design (target) spectrum proposed by various researchers require that a number of real recorded seismic accelerograms of appropriate frequency content is available. To by-pass this requirement, a previously established in the literature probabilistic approach to yield simulated earthquake records whose response spectrum achieves on average a certain level of agreement with a target spectrum is employed in the present paper. At the core of the above method lies the adoption of an appropriate parametric power spectrum model capable of accounting for various site-specific soil conditions. In this regard, the potential of two different, commonly, used spectral forms is evaluated for this purpose in context with the design spectrum defined by the European Code provisions. Next, an iterative wavelet-based matching procedure is applied to the thus acquired records to enhance, individually, the agreement of the corresponding response spectra with the targeted one. Special attention is paid to ensure that the velocity and the displacement time histories associated with the finally obtained artificial accelerograms are physically sound by means of appropriate baseline correction techniques.

Keywords: response spectrum; artificial accelerograms; stochastic process; harmonic wavelets

INTRODUCTION

Contemporary code provisions define seismic severity by means of a set of design response spectra to be used, readily, in conjunction with linear static or dynamic analyses for the earthquake resistant design of ordinary structures. Nevertheless, additional nonlinear dynamic time history analyses are required for the aseismic design of non-conventional structures or of facilities of critical importance. In this case the seismic severity is represented by a collection of recorded or numerically simulated seismic time histories which must satisfy specific criteria of compatibility with the elastic design spectra.

Recently, the problem of generating design spectrum compatible earthquake records has been addressed by incorporating deterministic numerical schemes (Karabalis et al., 2000), neural networks (Ghaboussi and Lin, 1998), and certain signal processing techniques, such as the wavelet transform (Mukherjee and Gupta, 2002), the adaptive chirplet transform (Wang et al., 2002), and the empirical mode decomposition (Wen and Gu, 2004). In all of the above, and in most of the proposed in the literature methods, a suite of real seismic accelerograms is assumed to be available to the designer. Ideally, it should comprise signals recorded at sites of such soil conditions and during earthquake events of such characteristics so that their intensity and spectral content can be related to the certain

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design spectrum with which compatibility is ultimately pursued. Even though databases of recorded accelerograms are being increasingly populated, the formation of such a suite of signals may not be readily feasible for certain seismically prone regions.

In this paper, a stochastic approach originally established by Spanos and Vargas Loli (1985), is adopted to generate an arbitrarily large suite of earthquake records whose average displacement response spectrum bears close resemblance to a given design (response) displacement spectrum. Specifically, a simulated earthquake accelerogram is construed as a sample of a nonstationary zero-mean random process characterized by an appropriately defined uniformly modulated evolutionary power spectrum (Priestley, 1965). The latter is related to the design spectrum by making use of an approximate formula for the probability density of the amplitude of the response of a single-degree-of-freedom oscillator to a non-stationary stochastic excitation (Spanos and Solomos, 1983). The thus generated seismic accelerograms can then be individually modified using any of the suggested in the literature technique to improve the agreement of their response spectra with the considered design spectrum (Preumont, 1989, Carballo and Cornell, 2000, Mukherjee and Gupta, 2002). Herein, a matching technique incorporating the wavelet transform developed by Mukherjee and Gupta (2002), in conjunction with the generalised harmonic wavelets (Newland, 1994; Spanos et al., 2005), is adopted for the purpose.

To demonstrate the effectiveness of the proposed approach an elastic displacement response spectrum defined by the European Standards (CEN, 2003), pertaining to a specific ground type and design ground acceleration is selected as the target design spectrum. The requisite parameters for the complete analytical definition of two different forms of exponentially modulated power spectra are determined. The forms examined are the Kanai-Tajimi (Kanai, 1957), and the Clough-Penzien (Clough and Penzien, 1993), power spectrum. Ensembles of synthetic time histories compatible with the considered evolutionary power spectra are generated and their average response spectra are compared to the target spectrum to assess the potential of the corresponding spectral forms to yield an acceptable level of matching. Furthermore, the effectiveness of the harmonic wavelet transform for properly modifying a single accelerogram, arbitrarily selected out of the generated ensembles, so that its displacement response spectrum to be in a very close agreement to the target spectrum is illustrated. Note that the fact that artificial accelerograms require certain baseline corrections to yield realistic displacement time histories is taken into account and is properly addressed in the case of the above modified single accelerogram.

THEORETICAL BACKGROUND

Probabilistic formulation of the simulation problem

The response of a linear single degree of freedom (SDOF) oscillator subject to ground acceleration $\ddot{u}_g(t)$ with zero initial conditions is governed by the equation

$$\begin{gathered}\ddot{x}(t)+2\zeta\omega_n\dot{x}(t)+\omega_n^2x(t)=-\ddot{u}_g(t)\\ x(0)=\dot{x}(0)=0\end{gathered}, \tag{1}$$

where $x(t)$ is the displacement trace of the oscillator relative to the motion of the ground, while ζ and ω_n are the damping ratio and the undamped natural frequency of the oscillator, respectively. The dot over a symbol denotes differentiation with respect to time t. In Equation (1), let $\ddot{u}_g(t)$ be a zero-mean nonstationary stochastic process of the separable kind, given by

$$\ddot{u}_g(t)=A(t)y(t) \tag{2}$$

where $A(t)$ is assumed to be a slowly-varying in time function that modulates a Gaussian zero-mean stationary stochastic process $y(t)$. Then, the two-sided evolutionary power spectrum $S(t,\omega)$

characterizing the uniformly modulated process $\ddot{u}_g(t)$ in the domain of frequencies ω can be analytically expressed as (Priestley, 1965)

$$S(t,\omega)=\left|A(t)\right|^2 S(\omega), \tag{3}$$

where $S(\omega)$ is the power spectrum of the stationary process $y(t)$.

Furthermore, assume that $S(t,\omega)$ attains significant values of the same order of magnitude over a broad frequency band throughout the duration of the input process $\ddot{u}_g(t)$, and consider the class of lightly damped oscillators (ζ<<1). It can then be argued that the response of such oscillators trails a pseudo-sinusoidal motion with amplitude, $a(t)$, and phase, $\varphi(t)$, corresponding to processes of slow temporal evolution statistics. That is:

$$x(t)=a(t)\cos\left[\omega_n t+\varphi(t)\right]. \tag{4}$$

Under the aforementioned assumptions, it can be proved that the probability density function of the response amplitude is a time dependent Rayleigh distribution (Spanos and Solomos, 1983), of the form

$$p(a,t)=\frac{a}{\sigma_x^2(t)}\exp\left(\frac{-a^2}{2\sigma_x^2(t)}\right), \tag{5}$$

in which the function $\sigma_x^2(t)$ is the variance of the amplitude, given by the equation

$$\sigma_x^2(t)=\frac{\pi}{\omega_n^2}\exp(-2\zeta\omega_n t)\int_0^t \exp(2\zeta\omega_n\tau)S(\omega_n,\tau)\,d\tau . \tag{6}$$

Following similar lines as in Spanos and Vargas Loli (1985), the evolutionary power spectrum $S(\omega,t)$ of the process $\ddot{u}_g(t)$ is related to a given (target) displacement response spectrum S_d by the equation

$$S_d(\omega_n,\zeta)=\sqrt{\frac{\pi}{2}}\sigma_{x(\max)}(\omega_n,\zeta), \tag{7}$$

where $\sigma_{x(max)}$ is the maximum attainable value of the standard deviation of the amplitude in time. Evidently, Equations (6) and (7) set the simulation problem of generating displacement response spectrum compatible earthquake time histories on a probabilistic basis.

Spectral form of the underlying evolutionary power spectrum

Obviously, appropriate analytical expressions for the modulation function $A(t)$ and the power spectrum $S(\omega)$ must be adopted to pursue a solution to the previously described simulation problem. To this end, the Bogdanoff-Golberg-Bernard (BGB) envelope function given by (Bogdanoff et al., 1961)

$$A(t)=Ct\exp\left(-\frac{r}{2}t\right) \tag{8}$$

is used, where C and r are positive parameters to be determined. This function has been widely utilized for the definition of separable non-stationary stochastic process models to account for the time-decaying intensity preceded by a short initial period of growth of typical recorded earthquake accelerograms. Recently, the "slowly-varying" assumption for the BGB function was ascertained to be reasonable by means of the adaptive chirplet transform (Politis et al., 2006).

Furthermore, the so-called Clough-Penzien power spectrum (CP), defined by (Clough and Penzien, 1993)

$$S(\omega)=\frac{\left(\frac{\omega}{\omega_f}\right)^2}{\left(1-\left(\frac{\omega}{\omega_f}\right)^2\right)^2+4\zeta_f^2\left(\frac{\omega}{\omega_f}\right)^2}\frac{1+4\zeta_g^2\left(\frac{\omega}{\omega_g}\right)^2}{\left(1-\left(\frac{\omega}{\omega_g}\right)^2\right)^2+4\zeta_g^2\left(\frac{\omega}{\omega_g}\right)^2};|\omega|\leq\omega_b \tag{9}$$

constitutes a viable choice for the spectral representation of the process $y(t)$. In Equation (9), ω_f, ζ_f, ω_g and ζ_g are introduced as positive parameters, and ω_b signifies the highest frequency of interest.

The main asset of the CP spectrum is that it lends itself to a clear physical interpretation associated with site specific soil conditions. According to this model, propagating seismic waves emitted by a source of stationary band-limited white noise, the seismic fault, are first filtered by a high-pass (HP) filter. The transfer function of this filter coincides with one of a linear SDOF system of natural frequency ω_f, and of damping ratio ζ_f. It can be argued that the HP filter captures the impact of the geological formations of the crust of the Earth, the bedrock. Then, the well-known band-pass Kanai-Tajimi (KT) filter is used in cascade to account for the resonance effect of the relatively soft surface soil deposits, modeled by a second linear SDOF system with natural frequency ω_g and damping ratio ζ_g (Kanai, 1957).

However by adopting the CP spectral form, the complexity of the simulation problem is significantly increased since four more undetermined parameters are introduced in addition to the required parameters, two, for the definition of the BGB modulating envelop. One may be tempted to consider a KT spectrum and thus completely eliminate the first ratio in Equation (9), in order to reduce the total number of the parameters to be determined to four. Interestingly, this simplification preserves some of the soil characterization properties of the CP spectrum and has been extensively used in the past for the purpose (e.g. Lai, 1982). However, this will allow for the presence of non-negligible low frequency content in the spectral representation of the seismic input process $\ddot{u}_g(t)$. This attribute often contradicts with what is observed in recorded earthquake signals pertaining to real seismic events (Sólnes, 1997).

Approximate pointwise solution of the simulation problem

An exact answer to the problem defined by Equations (6)~(9) would involve the solution of the first-passage problem for a linear SDOF system to a nonstationary excitation, which is mathematically intractable. Herein, an approximate solution as proposed in Spanos and Vargas Loli (1985) is pursued. Specifically, it is sought to approximately satisfy Equation (7) in a pointwise manner, at a certain set of frequencies $\{\omega_{n(k)}\}$ for k= 1,…,M, in the least square sense. This leads to a least squares minimization problem which for the case of the BGB modulation function reads as

$$\min\left\{\sum_{j=1}^{2M}\left(S_j-\sigma_j\right)^2\right\}, \tag{10}$$

where

$$S_j=\begin{cases}S_d^2\left(\omega_{n(j)}\right), & j=1,\ldots,M\\ 0 & , j=M+1,\ldots,2M\end{cases}, \tag{11}$$

and

$$\sigma_j = \begin{cases} \dfrac{\pi^2 C^2 t_j^2 \exp\left(-rt_j\right)}{4\zeta\omega_{n(j)}^3} S\left(\omega_{n(j)}\right), \quad j = 1,\ldots,M \\ \dfrac{C^2 S\left(\omega_{n(j-M)}\right)\exp\left(-rt_{j-M}\right)}{\gamma_{j-M}^3}\Big[\gamma_{j-M}^2\left(2t_{j-M} - rt_{j-M}^2\right) - 2\gamma_{j-M}\left(1 - rt_{j-M}\right) - \\ -2r + 4\zeta\omega_{n(j-M)}\exp\left(-\gamma_{j-M}t_{j-M}\right)\Big], \quad j = M+1,\ldots,2M \end{cases} \tag{12}$$

In Equation (12) $\gamma_k = 2\zeta\omega_{n(k)} - r$ and t_k denotes the point in time when the variance of the amplitude for the various (t_k, ω_k) combinations given by Equation (6) of the SDOF oscillator of natural frequency $\omega_{n(k)}$ reaches an absolute maximum value; mathematically this is represented by setting the first derivative of Equation (6) equal to zero. Clearly, in Equations (10)~(12) the unknowns to be determined are the set of *m* time instants $\{t_k\}$, *C*, *r*, plus all necessary parameters for the complete definition of $S(\omega)$, while the number of equations is *2m*. In practice, the number of equations will always be greater than the total number of unknowns, since for an acceptable approximation to the solution of the problem at hand several tenths of points $\{\omega_{n(k)}\}$ along the frequency band of concern should be considered. Thus, Equations (10)~(12) define a typical high-dimensional overdetermined non-linear least-square fit optimization problem.

Synthesis of evolutionary spectrum compatible acceleration records

Upon determination of the evolutionary power spectrum $S(t,\omega)$, an arbitrarily large number of compatible nonstationary accelerograms can be generated via an appropriate random field simulation technique. Conveniently, in the case of the uniformly modulated nonstationary stochastic processes any method for the generation of stationary time histories $y(t)$ compatible with a specific power spectrum $S(\omega)$ can be employed for synthesizing the non-stationary records $\ddot{u}_g(t)$, as Equation (2) suggests. In this study, the so-called ARMA simulation method is used. Specifically, a discrete stationary stochastic process $\tilde{y}$ is generated as the output of a linear time-invariant autoregressive moving average (ARMA) digital filter subject to band-limited white noise input (Spanos and Mignolet, 1986). The s-sample of an ARMA(p,q) process is computed recursively as a linear combination of the previous p samples plus a convolution term as

$$\tilde{y}[s] = -\sum_{k=1}^{p} b_k \tilde{y}[s-k] + \sum_{l=0}^{q} c_l w[r-l]. \tag{13}$$

In this equation b_k and c_l are the coefficients of the ARMA filter; the symbol *w* denotes a discrete white noise process band-limited to ω_b. To avoid aliasing the sampling period of the discrete process T_s must be less or equal to the Nyquist frequency. That is

$$T_s \le \frac{\pi}{\omega_b}. \tag{14}$$

The coefficients b_k and c_l are determined so that the squared modulus of the frequency response of the ARMA filter matches the power spectrum $S(\omega)$. That is

$$S(\omega) = \left|H\left(e^{i\omega T_s}\right)\right|^2 , \tag{15}$$

where H denotes the transfer function of the ARMA filter which in Z-transform notation reads as

$$H(z) = \frac{\sum_{l=0}^{q} c_l z^{-l}}{1 + \sum_{k=1}^{p} b_k z^{-k}}. \tag{16}$$

In the ensuing analysis the auto/cross-correlation matching (ACM) procedure is used to establish the unknown coefficients. According to this scheme, a relatively long autoregressive (AR) digital filter is first constructed by way of the standard linear prediction theory, to approximate the target power spectrum. Then, matching of both the output auto-correlation and the input/output cross-correlation sequences between this preliminary AR and the final ARMA model is enforced. Eventually, the coefficients of the ARMA filter are calculated by solving a p+q by p+q system of linear equations. More details on the ACM procedure can be found in Spanos and Zeldin (1998).

Enhanced matching of synthesized records using the Harmonic Wavelet Transform

Let *f(t)* be a single time history record generated by the above mentioned procedure associated with an analytically defined design displacement (target) spectrum $S_d(\omega)$ prescribed by an aseismic regulation code. In general, it is not expected that the displacement response spectrum of *f(t)* will be close enough to the target to satisfy the commonly mandated matching criteria for artificial accelerograms; see for instance CEN (2003). Nevertheless, any judiciously selected *f(t)* can be appropriately modified in order to improve the agreement of its response spectrum with the target one. In this respect, an iterative matching procedure incorporating the wavelet transform (WT) proposed by Mukherjee and Gupta (2002) is adopted. Adopted by Newland (1994), the generalized harmonic wavelets are used herein for the decomposition of the original time history. The main reason behind this choice is that harmonic wavelets allow for perfect reconstruction of any finite energy signal, and there exists an efficient algorithmic process for this purpose (Newland, 1997).

A generalized harmonic wavelet of (*m,n*) scale and *k* position in time is defined in the frequency domain by the equation (Newland,1994)

$$\Psi_{m,n}(\omega) = \begin{cases} \dfrac{1}{2\pi(n-m)} \exp\left(\dfrac{-i\omega k}{n-m}\right), & 2\pi m \le \omega \le 2\pi n \\ 0 & , \quad otherwise \end{cases} \tag{17}$$

The associated continuous Harmonic Wavelet Transform (HWT) reads (Newland, 1994)

$$\left[W_\psi f\right](m,n,k) = (n-m) \int_{-\infty}^{\infty} f(t) \psi^*_{m,n}\left(t - \frac{k}{n-m}\right) dt \tag{18}$$

where $\psi_{m,n}(t)$ is the inverse Fourier transform of Equation (17), and the symbol (*) denotes complex conjugation. Clearly, the HWT decomposes the signal *f(t)* into several sub-signals $f_{m,n}(t)$, each one of them corresponding to a certain band of frequencies defined by the (*m,n*) pair, so that (Spanos et al., 2005)

$$f(t) = \sum_{m,n} f_{m,n}(t), \tag{19}$$

where

$$f_{m,n}(t) = 2\,\mathrm{Re}\left\{ \sum_{k=0}^{n-m-1} \left[W_\psi f \right](m,n,k)\,\psi_{m,n}\left(t - \frac{k}{n-m} \right) \right\}. \tag{20}$$

Thus, an iterative scaling procedure can be devised where at the vth iteration all sub-signals are updated using the equation

$$f_{m,n}^{(v+1)}(t) = f_{m,n}^{(v)}(t) \frac{\int_{2\pi m}^{2\pi n} S_d(\omega)\,d\omega}{\int_{2\pi m}^{2\pi n} D^{(v)}(\omega)\,d\omega}, \tag{21}$$

where $D^{(v)}(T)$ is the displacement response spectrum related to $f^{(v)}(t)$ obtained by Equation (19). Note that a sufficient number of properly defined (m,n) pairs should be used to cover the whole frequency bandwidth of interest.

NUMERICAL EXAMPLE

In what follows, certain results elucidating certain aspects of the proposed method are presented. The target spectrum S_d that is used is the elastic displacement response spectrum prescribed in the Annex A of EC8 for high seismicity regions (Type 1), damping ratio ζ= 5%, design ground acceleration α_g= 0.16g (g= 981 cm/sec^2), and ground type A (CEN, 2003).

The minimization problem outlined by Equations (10)~(12) has been carried out utilizing the Levenberg-Marquardt algorithm with line search (Nocedal and Wright, 1999), for both the Clough-Penzien (CP), and the Kanai-Tajimi (KT) spectra modulated by the BGB function. Matching was attempted at 70 points for the CP case, and at 90 points for the KT case, in the interval [0.52, 314.16] (rad/sec) of the frequency axis, which is mapped onto the interval [0.02, 12] (sec) on the axis of periods. As it can be seen in Figure 1, excellent pointwise agreement between the target and the approximating spectra is achieved. The pertinent numerical values of the free parameters necessary to completely define the spectral forms under consideration are provided in Table 1. The thus defined evolutionary power spectra are shown in Figure 2. It is observed that they remain relatively broad throughout their effective duration, and that their energy becomes negligible after 30 sec.

Table 1. Parameters for defining the spectral forms considered to match the target spectrum

Kanai-Tajimi case (KT)	Clough-Penzien case (CP)
C= 6.75 cm^2/sec^5	C= 6.63 cm^2/sec^5
r= 0.44 sec^{-1}	r= 0.41 sec^{-1}
ζ_g= 0.66	ζ_g= 0.64; ζ_f= 1.08
ω_g= 26.00 rad/sec	ω_g= 28.00 rad/sec; ω_f= 2.81 rad/sec

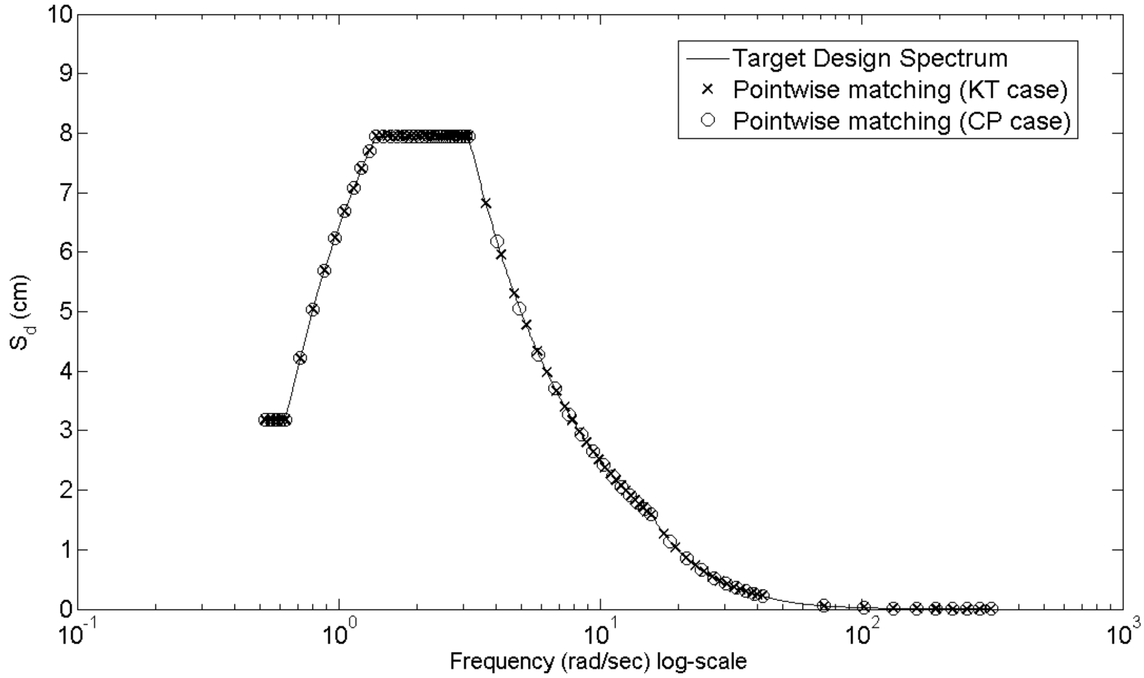

Figure 1. Pointwise least square matching with the target spectrum

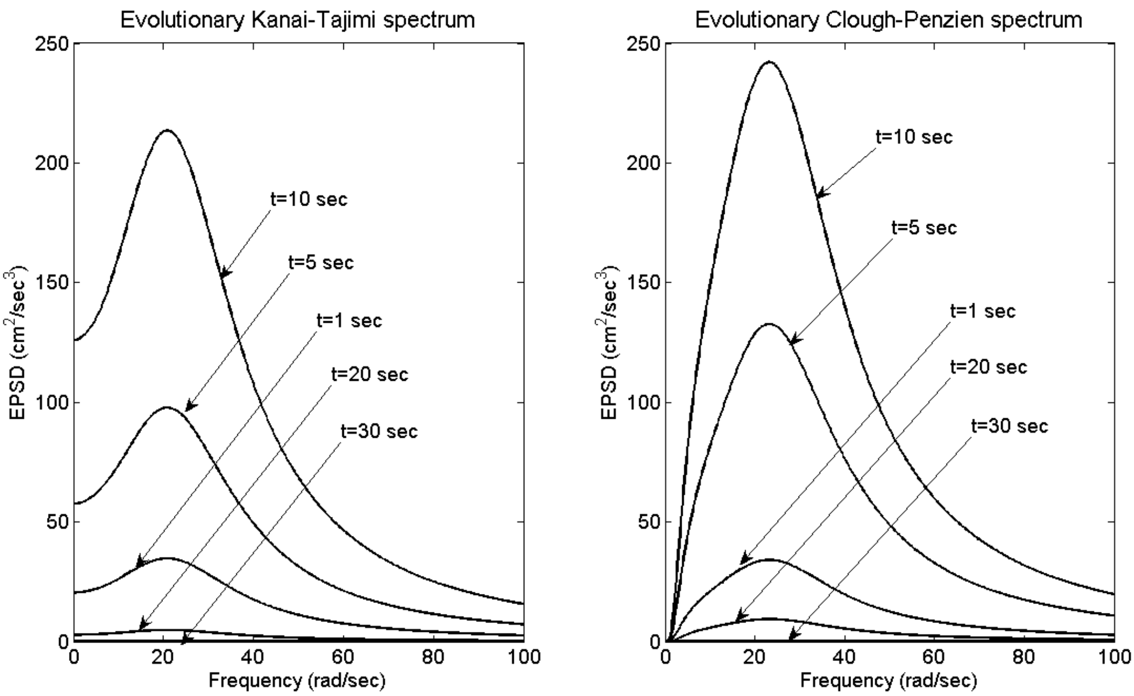

Figure 2. Evolutionary power spectral forms compatible with the target spectrum

Two different ensembles of 20 artificial accelerograms each compatible with the two above defined cases were synthesized using Equation (13), and a discrete form of Equation (2). The sampling interval has been taken equal to 0.01 sec to satisfy the condition of Equation (14). Average displacement response spectra for 5% damping for the two ensembles are shown in the first plot of Figure 3. The target spectrum is superimposed. The fact that the KT spectrum does not sufficiently suppress the low-frequency content, as it has been already discussed and can be deduced from Figure 2, affects ultimately the matching of the response spectra of the synthesized accelerograms with the target spectrum in the region of long periods, in an unacceptable fashion. Evidently, the KT spectrum is a poor choice for the purpose.

In the second plot of Figure 3, response spectra calculated from single accelerograms arbitrarily selected from the CP ensemble are shown on the top of the target spectrum to illustrate their statistical nature. Obviously, even though they do not yield an acceptable matching to the target spectrum, they can be regarded as reasonable first approximations and can be used as "initial seeds" to an iterative modification procedure as the one outlined by Equation (21).

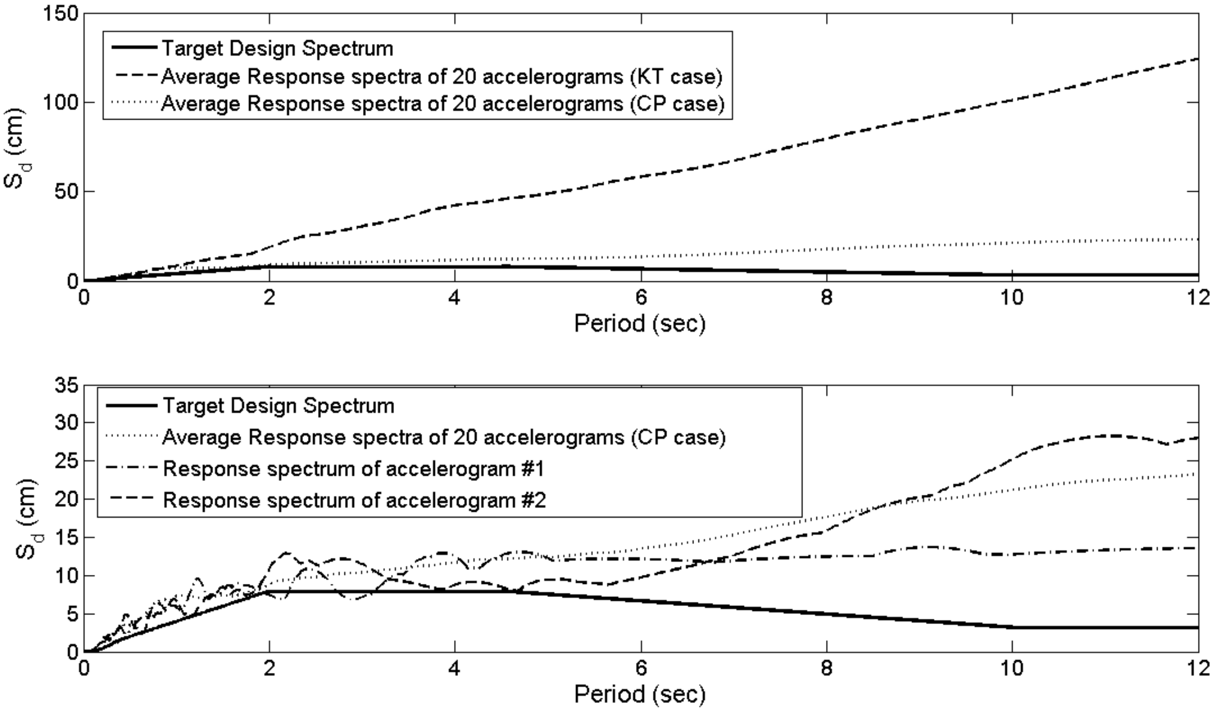

Figure 3. Displacement response spectra of simulated accelerograms

In Figure 4 the efficiency of the HWT in conjunction with Equation (21) to properly modify the frequency content of a given accelerogram so that its displacement response spectrum exhibits close similarity to a target spectrum is demonstrated. Purposely, a relatively "unfavorable" record is considered as the initial seed taken from the ensemble compatible with the CP case. By setting n-m= 4 in Equations (17) ~ (21) and after performing three iterations a satisfactory agreement between the target and the response spectrum of the modified accelerogram, marked as "uncorrected", is achieved. The acceleration, velocity and displacement time history traces of this record are presented in Figure 5. There is an obvious unnatural linear trend in the displacement trace which manifests the need for certain baseline corrections to be performed as in the case of any recorded accelerogram (Boore and Bommer, 2005). This need has been reported and addressed by some researchers in the past (e.g. Naeim and Lew (1995), Karabalis et al.,(2000), Mukherjee and Gupta (2002)). In this regard, processing with a Butterworth high-pass filter of order 6 and of cut-off frequency of 0.14Hz has been carried out and the "corrected" accelerogram shown in Figure 5 has been obtained. It is clearly far more realistic in terms of its velocity and displacement time history.

Notably, all code regulations evaluate the level of compatibility of artificial records with design spectra by means of criteria associated with pseudo-acceleration response spectra. Figure 6 presents the pseudo-acceleration response spectra of the uncorrected and the baseline corrected records of Figure 5. Interestingly, they are both found in a very good agreement with the target EC8 spectrum. However, in Figure 4 were the respective displacement response spectra are given, it is observed that the matching of the corrected record deteriorates significantly in the lower than 10 sec range of periods. This is because the high-pass filtering used for the baseline correction mostly affects the displacement trace of the record which mainly influences the displacement response spectrum, while it has limited effect on the acceleration trace and eventually on the pseudo-acceleration spectrum. At this stage, engineering discretion must dominate; the priority should be to produce an artificial accelerogram with a physically meaningful displacement trace, even if its displacement response spectrum does not attain perfect agreement with the target spectrum. Thus, the baseline corrected record is the most appropriate to be used, especially for the design of very flexible structures.

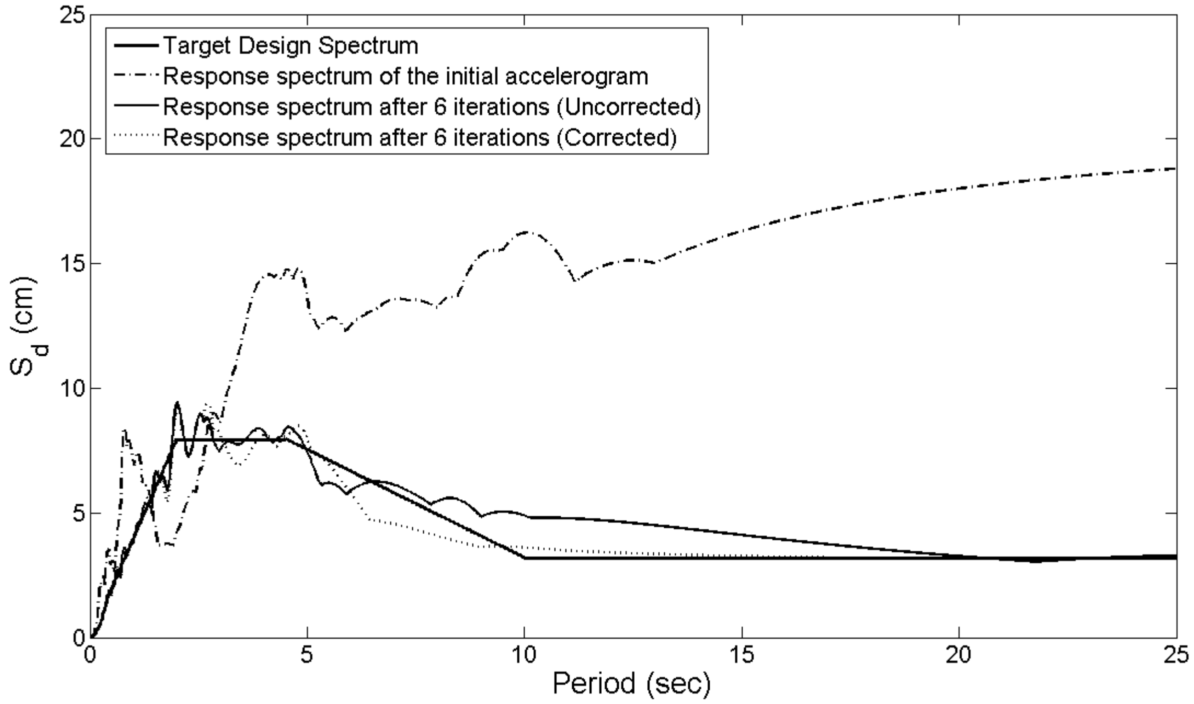

Figure 4. Displacement response spectra- Matching procedure for a single accelerogram

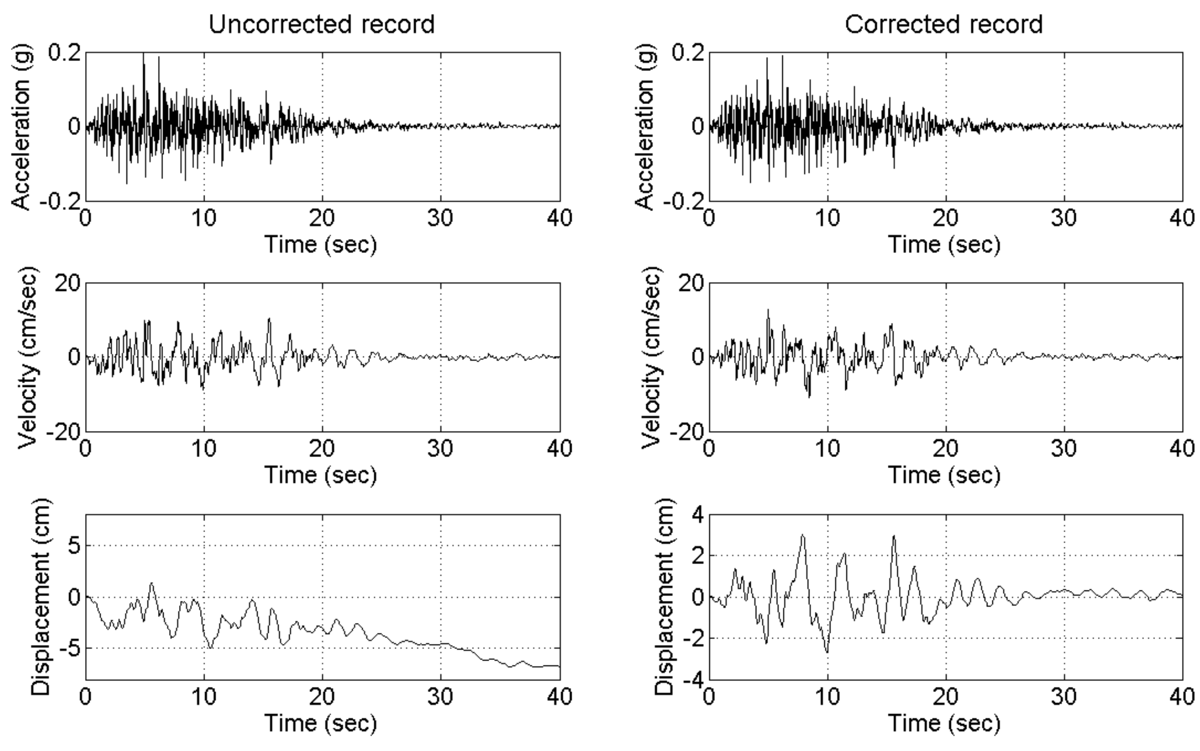

Figure 5. Acceleration, velocity and displacement simulated time histories

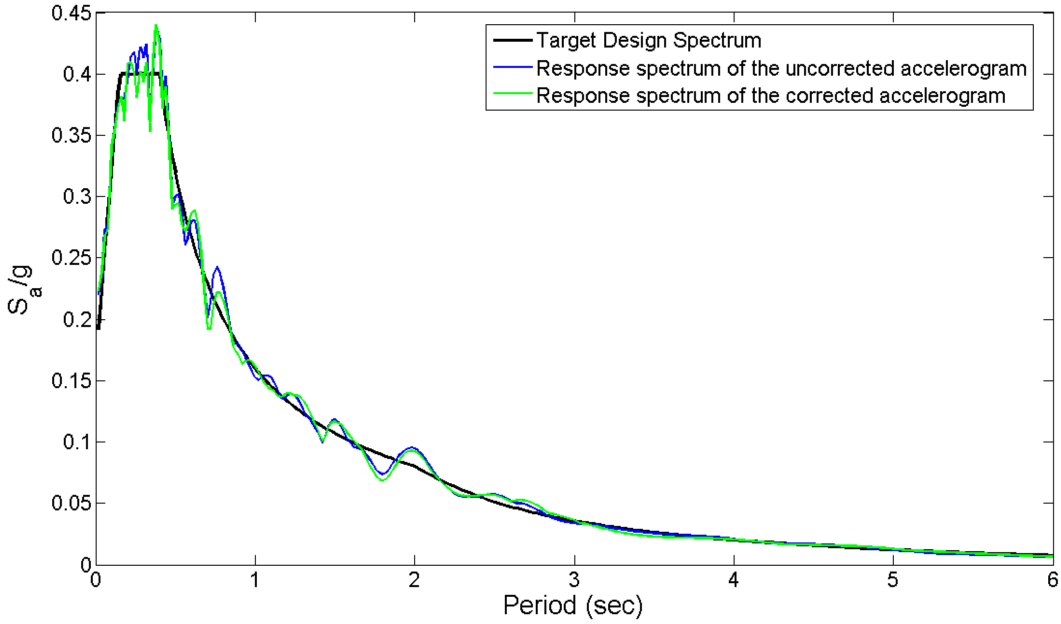

Figure 6. Pseudo-acceleration response spectra

CONCLUSIONS

An approach for simulating strong ground motion records compatible with a design (target) displacement spectrum specified by regulatory agencies for the aseismic design of structures has been presented. For this purpose, a previously established in the literature stochastic method has been extended in attempting to match point-wise the target spectrum with a uniformly modulated evolutionary power spectrum (EPS) that is parametrically defined by an analytical formula. Upon determination of the EPS, an ARMA model has been employed to synthesize nonstationary accelerograms compatible with the latter spectrum. It has been shown that the level of agreement of the mean response spectrum of these records with the target spectrum is highly dependent on the analytical form assumed for the EPS. Specifically, in view of derived numerical results associated with a design spectrum defined in EC8, it has been reported that an assumed Clough-Penzien spectral form yields better matching over the simpler Kanai-Tajimi form, especially in the range of long periods.

Furthermore, one of the individually generated accelerogram has bee modified iteratively to enhance the agreement of its response spectrum with the target one. In this manner, the need for collecting real recorded accelerograms can be by-passed. To this end, the harmonic wavelet transform has been employed successfully in an iterative acceleration modification scheme. Finally, the need to scrutinize the velocity and displacement traces and to effectively use standard baseline correction techniques to obtain records possessing realistic time-histories has been adequately illustrated and properly addressed.

Future work towards the enhancement and elucidation of certain aspects of the herein proposed method will include further experimentation with design spectra defined for various soil conditions and levels of seismic intensity, and consideration of alternative spectral forms for the definition of the EPS.

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