GOSCA
Generation Of Spectrum Compatible Accelerograms

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Abstract

The purpose of GOSCA is to generate spectrum compatible accelerograms. A full description and benchmarking of the method is given in [1]. It is summarized in this document.

One may distinguish three kinds of accelerograms: (i) real accelerograms, as recorded during earthquake events, (ii) synthetic accelerograms obtained from geological models, and (iii) artificial accelerograms which are numerically generated in such a way that their response spectrum corresponds to a target spectrum. Accelerograms generated by GOSCA are of this latter kind.

Let $S(T;\xi)$ be the target response spectrum. The generation procedure is an iterative process with the following steps.

1. According to the desired duration of the acceleration to be generated a time step Δt and a number of samples N are determined. They satisfy $N\Delta t = T$, the total duration of the generated accelerogram.

2. A first signal $u(t)$ is generated as a Gaussian delta-correlated noise with zero mean and unit variance; it is of course stationary.

3. A transient signal is obtained by windowing as
$$y^{(1)}(t) = f(t)\,u(t) \tag{1}$$
where the dimensionless windowing function is one of the following
$$f(t) = a_1 t\, e^{-a_2 t}, \quad \text{or} \quad f(t) = \begin{cases} (t/t_1)^2 & \text{for } 0 \le t \le t_1 \\ 1 & \text{for } t_1 \le t \le t_2 \\ exp\left[c\,(t-t_2)\right] & \text{for } t_2 \le t \end{cases} \tag{2}$$
with $a_1 = 0.45$, $a_2 = 0.167$ Hz, $c = 0.15$Hz and t_1 and t_2 are adjustable durations for the ramp and decreasing regimes. Notice $f(t)$ may also be chosen as the standard Hanning window.

4. A first accelerogram $a^{(1)}$ is obtained by imparting a realistic frequency content to $y^{(1)}$. This filtering operation is performed in the frequency domain as
$$A^{(1)}(\omega) = H_1(\omega)\,H_2(\omega)\,Y^{(1)}(\omega) \tag{3}$$
where $Y^{(1)}(\omega)$ is the Fourier transform of $y^{(1)}(t)$ and H_1 and H_2 are the Kanai-Tajimi and modified Kanai-Tajimi filters. The first accelerogram $a^{(1)}(t)$ is obtained by back-substitution of $A^{(1)}(\omega)$ in the time domain.

5. The response spectrum $S^{(1)}(T;\xi)$ of $a^{(1)}(t)$ is computed. It is of course different from the target spectrum $S(T;\xi)$ which has not been used so far. Follows then a series of adjustments to the initially generated accelerogram $a^{(1)}$.

6. A more appropriate accelerogram is then obtained by
$$A^{(2)}(\omega) = A^{(1)}(\omega)\,\frac{S(T;\xi)}{S^{(1)}(T;\xi)} \tag{4}$$
where the multiplication by the correction function aims at tuning the frequency response. The corresponding time domain accelerogram $a^{(2)}(t)$ is again obtained by back-substitution.

7. A recursive execution of this step is performed until the response spectrum of the generated accelerogram $a^{(k)}(t)$ matches the target spectrum. The convergence is addressed by least-square error for a set of 40 periods (by default) spread on the whole range of periods. Typically a couple of iterations are sufficient to obtain a sufficient accuracy (less than 3%, by default). If convergence is not obtained after 20 iterations, the whole process starts again.

References

[1] Denoël V., Calcul sismique d'ouvrages d'art (Seismic design of state-of-the art structures), University of Liège, Graduation thesis (2001). In French.