Development of semi-analytical Fourier-domain ground motion prediction model for rapid earthquake hazard scenario calculation

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Abstract

The choice of ground motion estimates used for seismic impact scenario calculation plays a key role in determining how well post-event impact estimates can be constrained. A common solution is to use synthetic waveform simulations, which are analytically accurate but usually have the disadvantage of using limited frequencies below 1 or 2 Hz and are computationally time consuming.

As a complementary approach, we aim to produce ground shaking estimates in the Fourier domain using a semi-analytical modelling technique to describe the Fourier Amplitude Spectra (FAS) in terms of their source, propagation and site components. The resulting FAS models obtained with this methodology contain information from a wide frequency range and require less computational time than fully analytical simulations (e.g. Bora et al. 2015). It is also possible to subsequently combine these results with an additional model of the corresponding phase spectra, to obtain realistic time-domain ground motion estimates. This activity is carried out in synergy with the RETURN Task 4.4 of VP3, which is dedicated to the improvement of real-time risk mitigation measures.

To improve the accuracy of the ground motion estimates, the spectral model must be carefully calibrated in advance by inverting observational data. A test area in north-eastern Italy was selected, where many regional monitoring institutions provide good data coverage (e.g. Bragato et al. 2021). A dataset of 1191 events that occurred in the area between 2016 and 2024 was selected and processed to create the spectral database used for the calibration. The calibration process aims on the one hand, to validate the theoretical choices made for the analytical model components and, on the other hand, to estimate the empirical components to be included in the forward model for the hazard calculation, namely the regional attenuation function and the site response functions. Once these components are empirically estimated for the region, the analytical model can be improved, for example by including a more complex seismic source description. The expertise gained in the application of the whole methodology to this test area will be then available to set up its application to other areas of interest.

Additionally, the calibrated model components can be used in near-real time to estimate the apparent source spectra from the observed FAS of new data. A timely and automatized fit of the source spectra for new events would produce near-real time estimates of the source parameters, such as seismic moment and stress drop, which would become available as input for other, more complex analytical simulations.

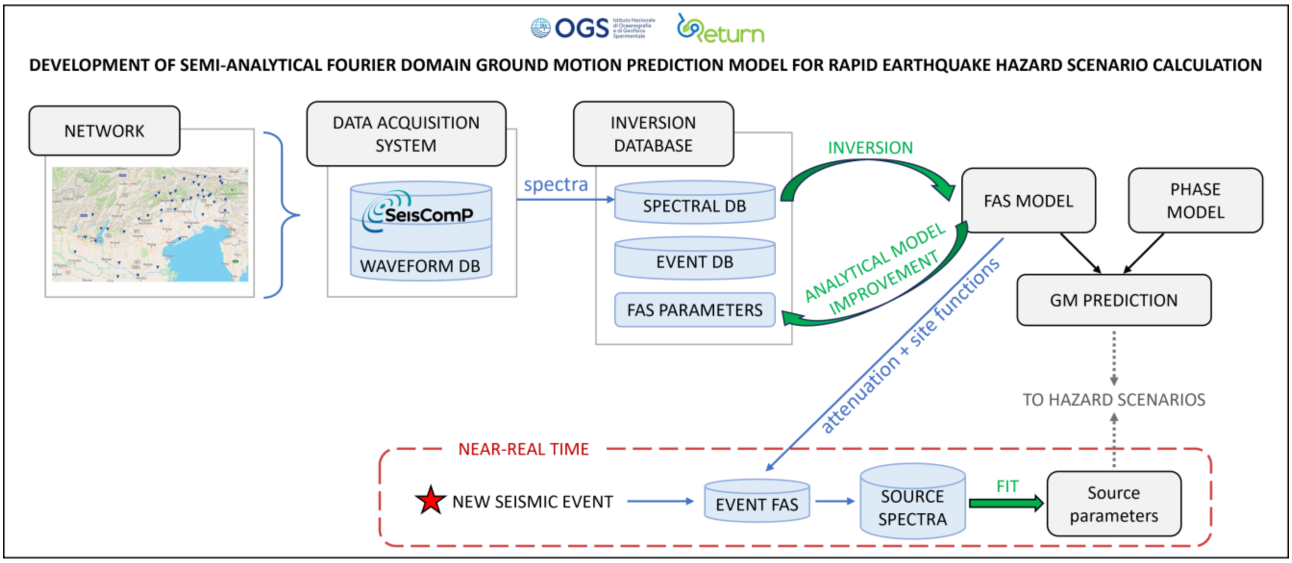

Figure 1 – Outline of the workflow with its main phases: data collection and processing to create the inversion database, inversion of FAS data and subsequent analytical FAS model improvement, generation of ground motion estimates by combination of FAS and phase models. The possible near-real time application to obtain estimates of seismic source parameters is also illustrated.

References

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