SSM
Scuola Superiore Meridionale

MERC PhD Project Proposal 2024/2025

Title of the research project:

Seismic hazard and quantitative risk analysis based on artificial intelligence-driven techniques.

Keywords (up to five)

Seismic risk analysis, artificial intelligence, earthquake engineering, ground motion model.

Supervisors (at least two from two different areas):

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Earthquake engineering, seismic hazard and risk analysis

Project description (max 5000 characters)

Natural hazards, such as earthquakes, pose significant threats to urban areas, endangering lives and causing damage to infrastructure and the economy. Accurate and timely seismic hazard and risk assessment is essential to mitigate these impacts. Traditionally, this process involves setting up ground motion models (GMMs), which establish a relationship between a ground motion intensity measure (IM) parameter and earthquake features such as magnitude and location, among others. The GMM is a key component in hazard analysis, enabling the probabilistic prediction of the IM of interest. However, the IM alone does not describe the entire accelerometric waveform that determines the dynamic response of a structure during an earthquake, and hazard analysis cannot predict, at the state-of-the-art, such a waveform.
Recent advances in artificial intelligence (AI), together with the increasing availability of ground motion recordings, offer new opportunities to enhance the efficiency and accuracy of seismic hazard and risk assessment. The overarching goal of this PhD project is to lay the basis for developing a framework for hazard assessment in terms of accelerometric waveforms, rather than traditional IMs, by leveraging AI-driven techniques. This requires GMMs for accelerometric waveforms, the development of which—potentially through functional data analysis and/or machine learning techniques—is a research topic to be explored during the PhD program. As a side-objective, the research program aims to promote, spread and operationalize the use of AI to develop a framework that implements, at any spatial scale, the most recent and advanced procedures for seismic hazard and risk analysis according to the state-of-the-art, such as, for example, seismic hazard analysis accounting for the effect of seismic sequences (e.g., Iervolino et al., 2014), or seismic risk analysis for complex spatially-distributed infrastructural systems (e.g., Giorgio and Iervolino, 2016; Cito et al., 2023)
The expected outcome from the PhD program is a new generation of seismic hazard and risk assessment tools that are not only methodologically advanced but also accessible and operational

for real-world decision-making, both in long-term risk mitigation and in real-time emergency contexts (e.g., operational earthquake forecasting and loss forecasting; Marzocchi et al., 2014; Iervolino et al., 2015).

Relevance to the MERC PhD Program (max 2000 characters)

The research project aligns with the main objective of the MERC doctoral program, which aims to develop innovative methodological approaches for understanding and modelling risk of complex systems. The Ph.D. candidate will be trained to operate across a broad spectrum of disciplines, exploring methods traditionally used in earthquake engineering for hazard and risk assessment, and extending their application to machine learning techniques. The skills developed throughout the doctorate program will be applicable to various domains, including civil engineering, earthquake engineering, ground motion modelling and critical infrastructure.

Key references

Cito, P., Chioccarelli, E., & Iervolino, I. (2023). Conditional hazard for simplified multi-site seismic hazard and risk analyses. *Earthquake Engineering & Structural Dynamics*, *52*(2), 482-499.

Giorgio, M., & Iervolino, I. (2016). On multisite probabilistic seismic hazard analysis. *Bulletin of the Seismological Society of America*, *106*(3), 1223-1234.

Iervolino, I., Chioccarelli, E., Giorgio, M., Marzocchi, W., Zuccaro, G., Dolce, M., & Manfredi, G. (2015). Operational (short-term) earthquake loss forecasting in Italy. *Bulletin of the Seismological Society of America*, *105*(4), 2286-2298.

Marzocchi, W., Lombardi, A. M., & Casarotti, E. (2014). The establishment of an operational earthquake forecasting system in Italy. *Seismological Research Letters*, *85*(5), 961-969.

Joint supervision arrangements

Weekly meetings with the primary supervisor or both supervisors will be scheduled throughout the entire research program (at least two meetings per week). All supervisors are based in their offices, ensuring daily in-person support for the Ph.D. candidate.

Location and length of the study period abroad (min 12 months)

The ETH Zurich is the primary host for the study period abroad.

Any other useful information

The first supervisor has research partnerships with the insurance industry, which is widely interested in advanced tools for quantitative risk analysis and may be involved in the project eventually.

Please return this form via email by no later than 3rd May 2021 to merc@unina.it