LMS Seminar

14 March 2024 at 2:00 pm - Room Jean Mandel

Generative strategies to empower physics-based wave propagation with deep learning. Applications to earthquake engineering and structural health monitoring.

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ABSTRACT

In this work, we provide a quantitative assessment of how largely can earthquake groundmotion simulation and structural health monitoring benefit from deep learning generative techniques, blended with traditional numerical simulations. Two main frameworks are addressed: conditional generative approaches and neural operators. On one hand, generative adversarial learning and diffusions models are compared in a time-series superresolution context. The main task is to improve the outcome of 3D fault-to-site earthquake numerical simulations (accurate up to 5 Hz [1, 2]) at higher frequencies (5-30 Hz), by learning the low-to-high frequency mapping from seismograms recorded worldwide [3]. The generation is conditioned by the numerical simulation synthetic time-histories, in a one-to-many setup that enables site-specific probabilistic hazard assessment. On the same page, the power of Generative Adversarial Networks is successfully tackled to prove their applicability in the multi-fidelity rendering of experimental ultrasound non-destructive tests, based on the multi-modal Total Focusing Method [4], and in the prediction of the transient response of damaged shear-type multi-storey buildings [5]. In the latter case, the post-earthquake dynamic response of the multi-storey building is generated via adversarial learning technique under different damage conditions, starting from the relevant undamaged response. Finally, the successful use of neural operators to entirely replace cumbersome 3D elastic wave propagation numerical simulations is described [6], showing how this approach can pave the way to real-time large-scale digital twins of earthquake prone regions [7].

BIOGRAPHY

Filippo Gatti is Maître de Conférences at CentraleSupélec since 2019, affiliated to Laboratoire de Mécanique des Sols, Structures et Matériaux (MSSMat) until 2021 and at Laboratoire de Mécanique Paris-Saclay (LMPS) since 2022. He holds a PhD in Civil Engineering from Université Paris-Saclay and Politecnico di Milano (2017), as well as a MSc (2014) and BEng (2011) from Politecnico di Milano. He has been JSPS post-doctoral fellow at the Disaster Prevention Research Institute at Kyoto University (2018) and visiting researcher at the Earthquake Research Institute at The University of Tokyo (2021).

Filippo Gatti's research interests cover the physics-based simulation of wave propagation phenomena, focusing on earthquake engineering and ultrasound wave propagation for non-destructive testing. Since 2014, Filippo Gatti co-develops the high-performance software [SEM3D](https://github.com/sem3d/sem) and maintains its open-source release since 2023. SEM3D is CPU/GPU parallel implementation of the spectral element method applied to 3D elastoacoustic wave propagation in highly heterogeneous and non-linear media. SEM3D has been widely employed for blind earthquake simulation and seismic risk assessment of critical infrastructures, such as Kashiwazaki-Kariwa nuclear power plant (Japan) and the Cadarache ITER facilities. In this context, in 2023, Dr. Gatti's spin-off project, EASYRISK, has been selected as recipient of the POCUP(https://satt-paris-saclay.fr/nos-appels-a-candidatures/pocup) spin-off program by the SATT Paris-Saclay, aiming at enabling non-expert users with the realism of SEM3D, towards achieving physics-based seismic risk assessment. Since 2018, Dr. Gatti research activities encompass the use of advanced machine learning to improve the fidelity of the numerical solutions of complex wave propagation problems, by blending physics-based approaches with complex features learned from data.

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