ECCOMAS
European Community on
Computational Methods in
Applied Sciences

ECCOMAS Thematic Conference

10th International Conference on
Computational Methods in Structural Dynamics and Earthquake Engineering

COMPDYN 2025

15-18 June 2025 - Rhodes Island, Greece

An Open-Source Toolkit for Seismic Vulnerability Assessment

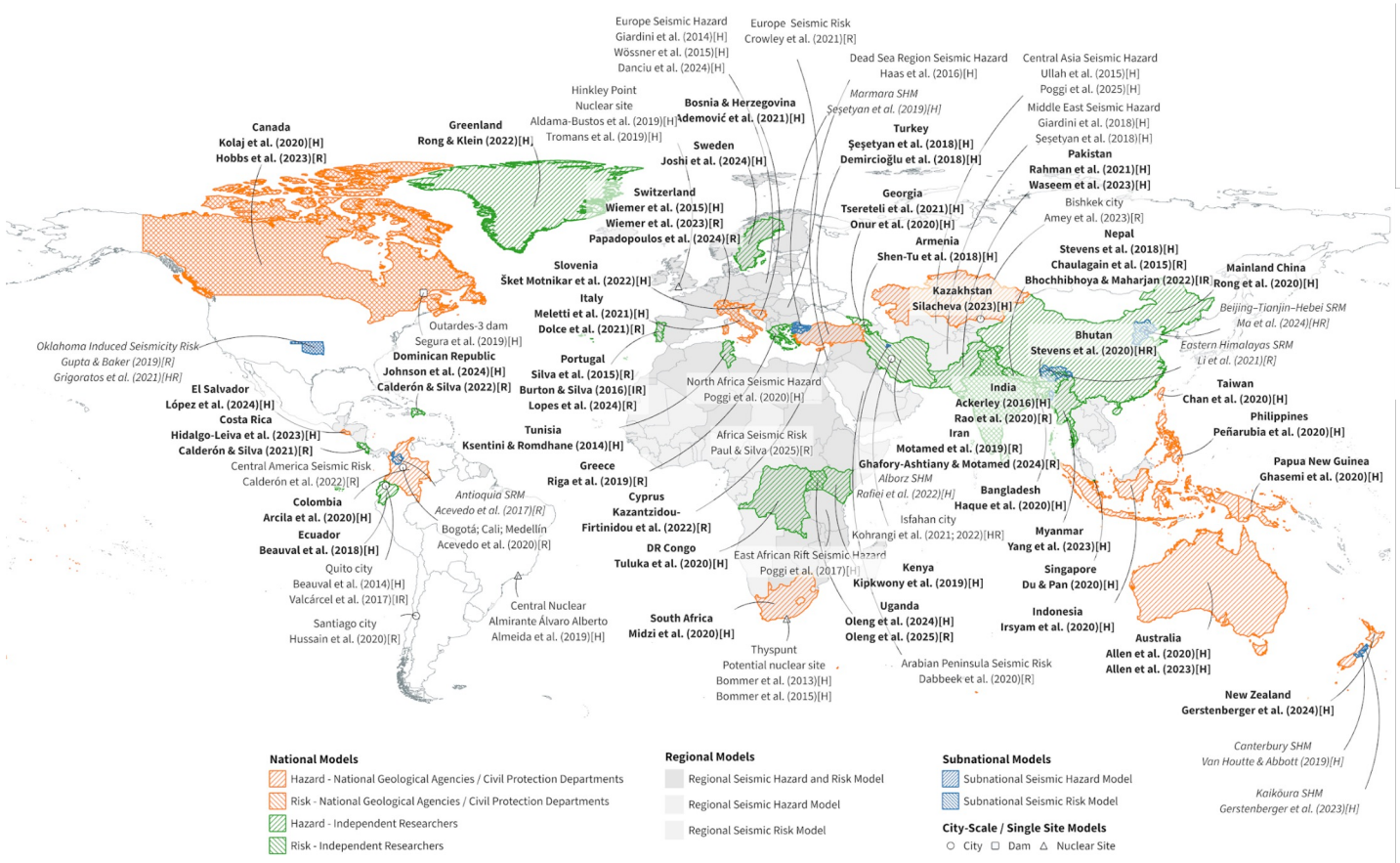
OpenQuake's Vulnerability Modellers Toolkit (OQ-VMTK)

Al Mouayed Bellah Nafeh,
Karim Aljawhari,
Vitor Silva



GEM
GLOBAL EARTHQUAKE MODEL working together to assess risk

GEM Foundation and Open Science



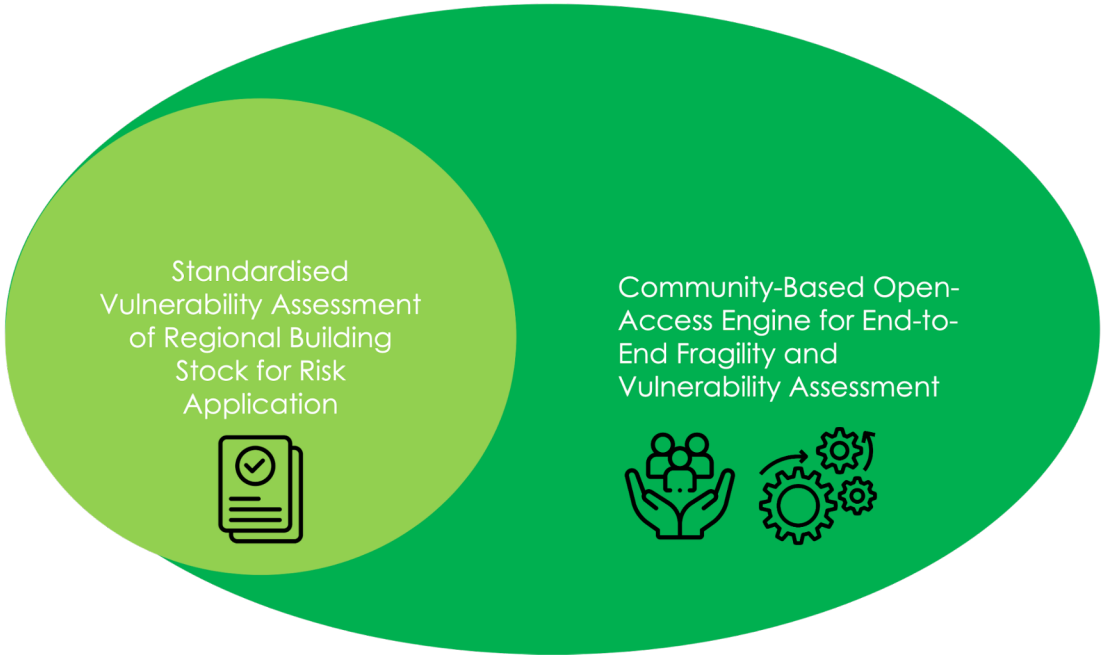
GEM
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OQ
OPENQUAKE
calculate share explore

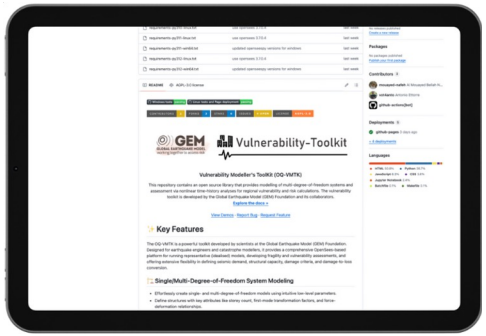
GEM Foundation and Open Science

Vulnerability-Toolkit





OpenQuake Vulnerability Modellers Toolkit

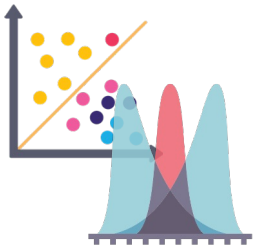


Core Library



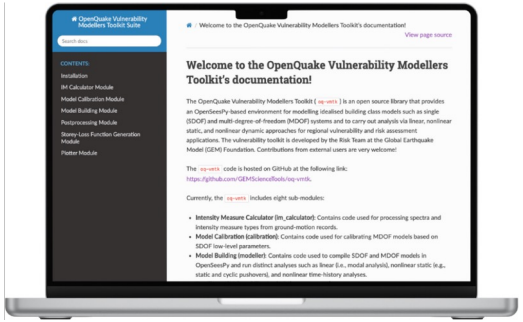
Modelling & Analysis

1



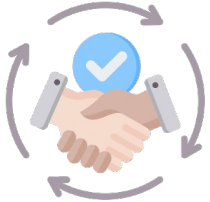
Postprocessing

2



Documentation

4



Continuous Integration

3



Data Visualisation

OpenQuake Vulnerability Modellers Toolkit

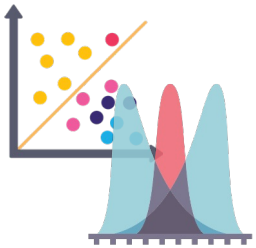
Python-Based Library

Hosted on GitHub

Windows



Modelling & Analysis 1



Postprocessing 2



Continuous Integration 4



Data Visualisation 3

Powered by OpenSees

OpenSees

Maintained by GEM

GEM GLOBAL EARTHQUAKE MODEL working together to assess risk

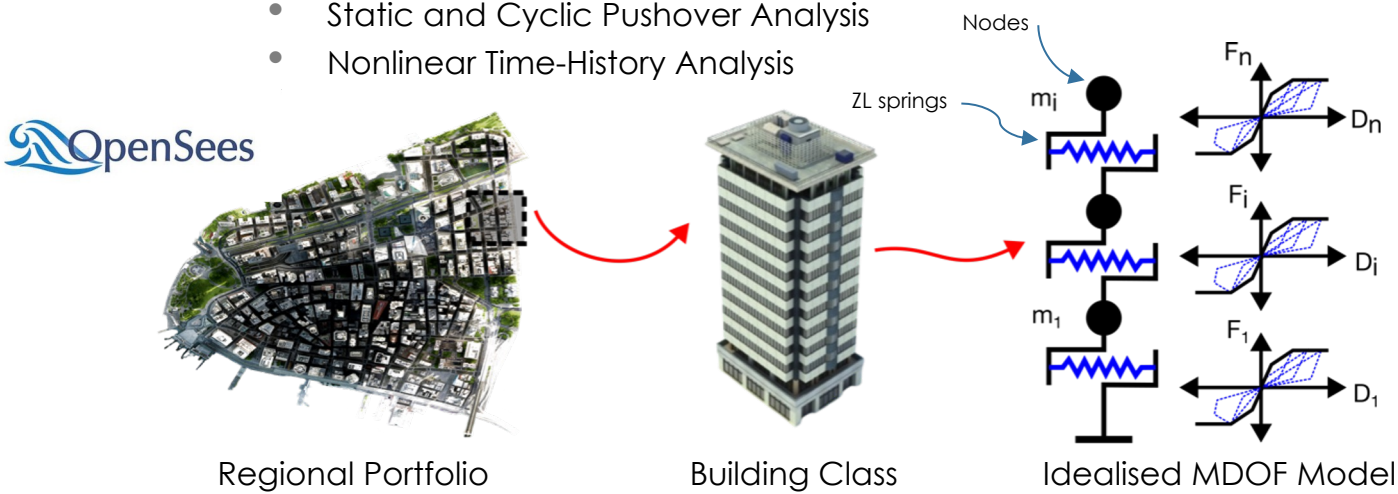
OQ OPENQUAKE calculate share explore

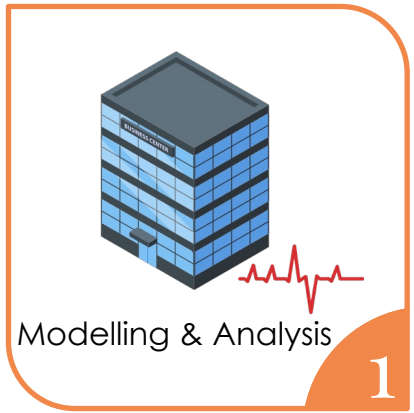
Linux

OpenQuake Vulnerability Modellers Toolkit

Model Builder & Analysis Module

- Powered by **OpenSeesPy**
- **Modelling** of idealised systems such as single-degree-of-freedom oscillators (SDoF), multi-degree-of-freedom stick models (MDoF)
- **Analysis** of idealised systems:
  - Gravity Analysis
  - Modal Analysis
  - Static and Cyclic Pushover Analysis
  - Nonlinear Time-History Analysis





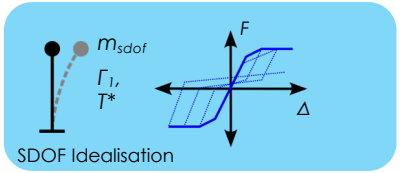
OpenQuake Vulnerability Modellers Toolkit

Model Calibration Module

- Calibrates **storey-based force-deformation relationships** based on Spectral Acceleration – Spectral Displacement input

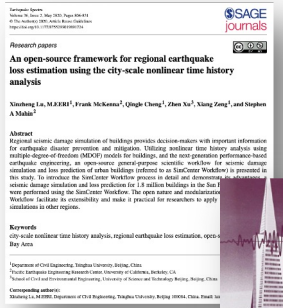


Building Class



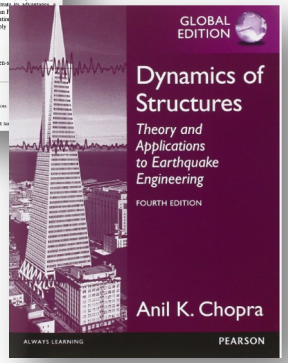
SDOF Idealisation

- ***SA - SD***: *Spectral Spectral Acceleration & Displacement*
- **Γ**: *Modal Transformation Factor*
- m_{sdof}: *Equivalent SDOF Mass*



An open-source framework for regional earthquake loss estimation using the city-scale nonlinear time history analysis

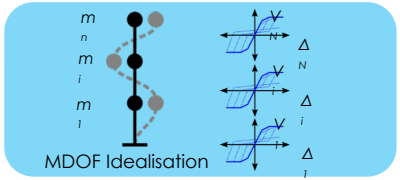
Lu et al. (2020)



Chopra (2022)



Building Class



MDOF Idealisation

- m_{mdof}: *Equivalent MDOF Mass*
- m_i: *Mass at Floor i*
- ϕ_1: *First-mode Shape*



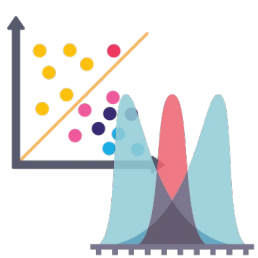
Modelling & Analysis

1

OpenQuake Vulnerability Modellers Toolkit

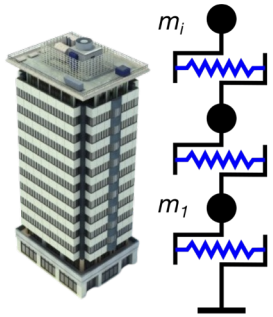
Postprocessing Module(s)

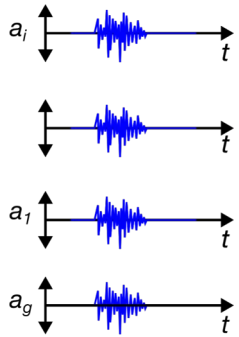
- **Processing NLTHA**: Cloud Analysis, Multiple Stripe Analysis
- **Fragility Function Derivation**: Conventional (e.g. Lognormal CDFs), State-of-the-Art Generalised Linear Models (e.g., Ordinal, Probit, etc.)
- **Vulnerability Function Derivation**
- **Calculation of risk metrics**: Average Annual Damage State Probabilities, Average Annual Loss Ratios

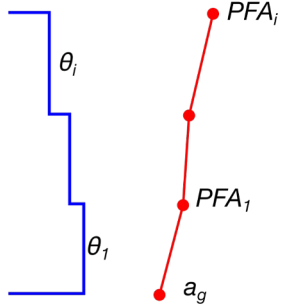


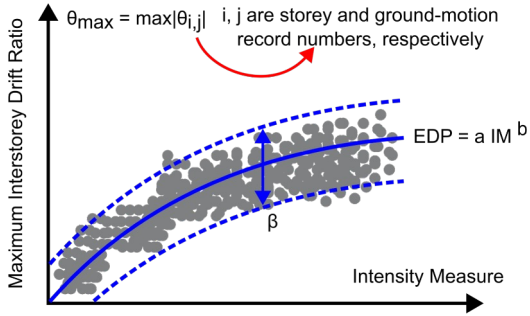
Postprocessing

2





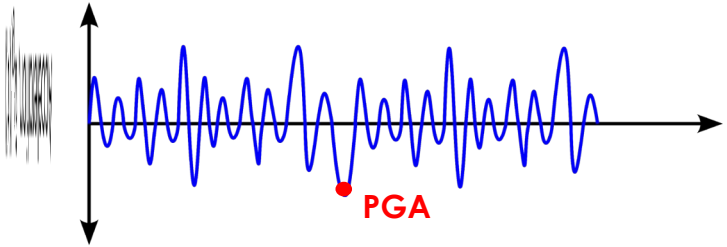


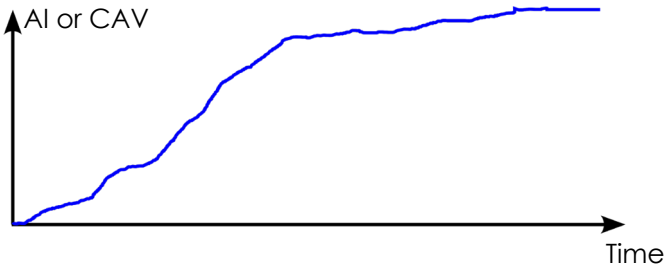


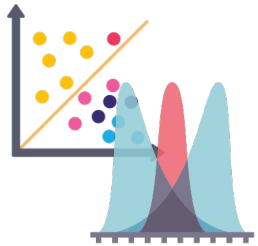
OpenQuake Vulnerability Modellers Toolkit

Postprocessing Module(s)

- **Record Processing**: Fetching Intensity Measures (e.g., Amplitude-Based, Structure-Based, Duration-Based, etc.)







Postprocessing

2

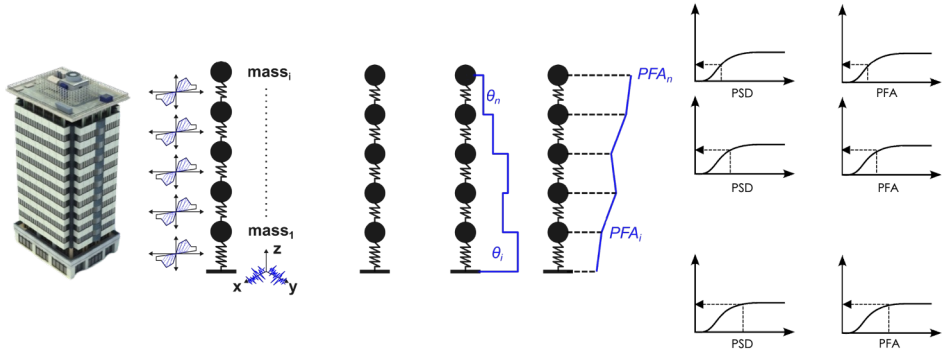
OpenQuake Vulnerability Modellers Toolkit

Postprocessing Module(s)

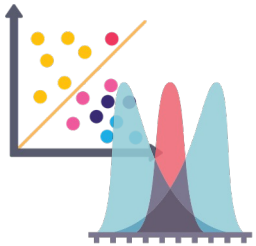
- **Storey-Loss Function Generation:** Component-based approach for storey-based loss assessment



SLF Implementation



SLF Application



Postprocessing

2

OpenQuake Vulnerability Modellers Toolkit

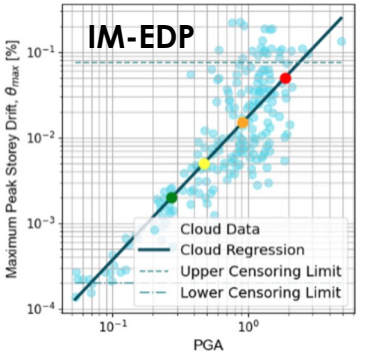
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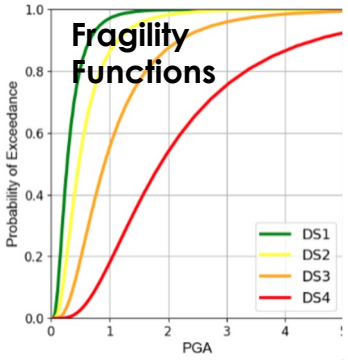


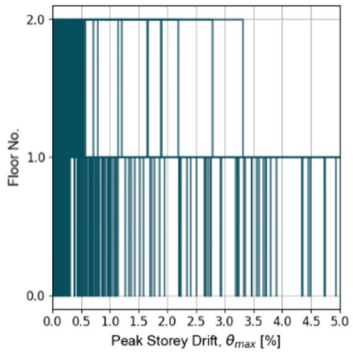
Data Visualisation

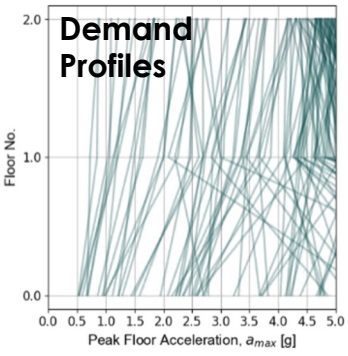
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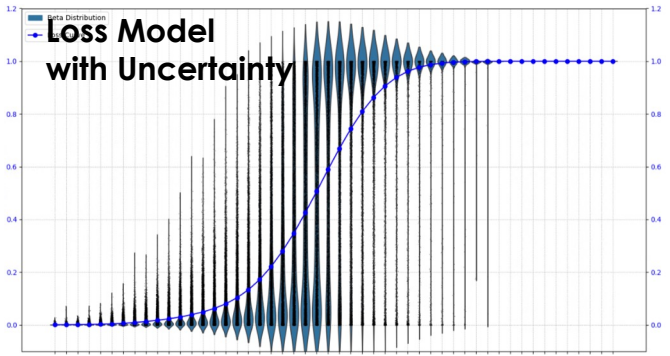
- **Visualise Analysis and Post-Processing Results**

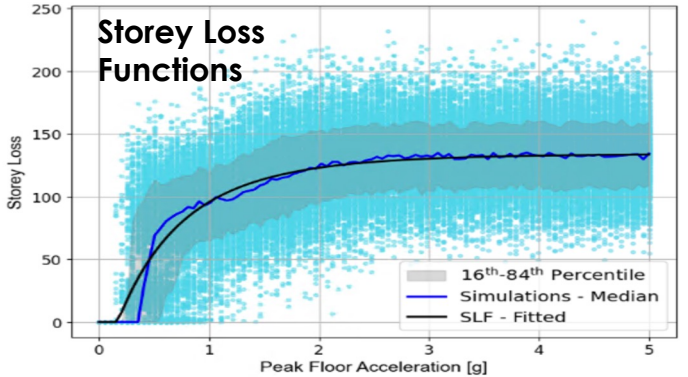








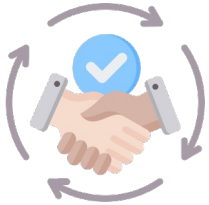




OpenQuake Vulnerability Modellers Toolkit

- **Unit Tests**
  - **Catch Bugs Early**: Identify and fix bugs at an early stage, reducing the cost and complexity of debugging later.
  - **Improve Code Quality**: Writing unit tests encourages better design, modularization, and clearer logic in the code.
  - **Enable Confident Refactoring**: Developers can safely refactor code, knowing that existing functionality is protected.
  - **Facilitate Continuous Integration**: Unit tests are essential for automated testing pipelines, ensuring that new changes don't break existing code.
  - **Document Intended Behavior**: Tests act as executable documentation, showing how code is expected to behave under various conditions.
  - **Boost Developer Confidence**: Developers are more confident deploying changes when robust unit tests validate correctness.

4



Continuous Integration



Debugging

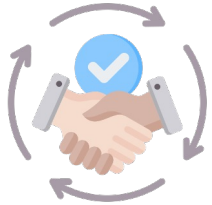


Practicality

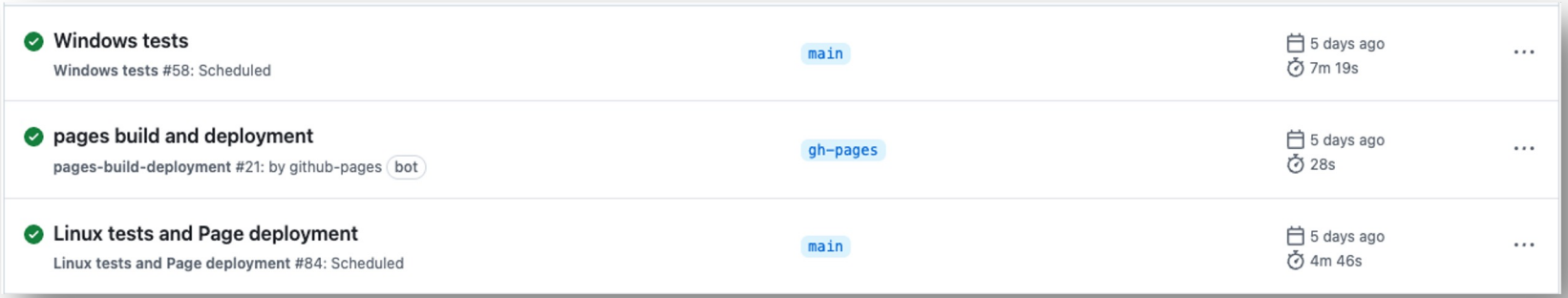
OpenQuake Vulnerability Modellers Toolkit

- ## Automation and Continuous Integration
  - **Automated Testing and Validation**: CI workflows automatically run tests and checks on every push or pull request, ensuring code quality and correctness.
  - **Improved Collaboration**: CI makes it easier for teams to work together by validating every contribution, preventing broken code from being merged into the main branch.
  - **Enforce Standards and Policies**: CI ensures consistent coding standards, test coverage, and security checks are applied automatically across all contributions.
  - **Supports Scalable Development**: As teams and projects grow, CI workflows in GitHub help maintain stability, reliability, and coordination across all contributions.

4



Continuous Integration



Demos



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GLOBAL EARTHQUAKE MODEL
working together to assess risk

Vulnerability-Toolkit

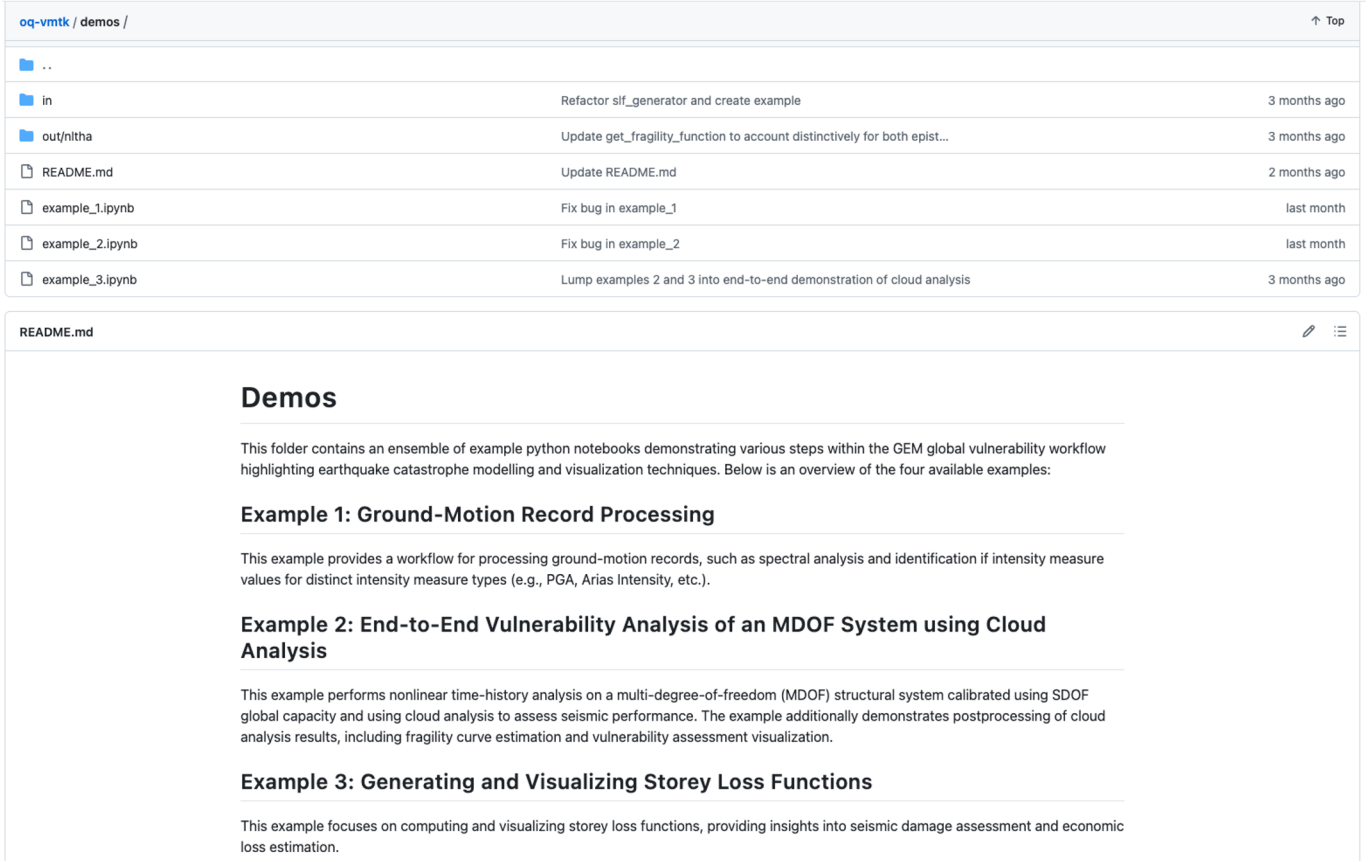
Vulnerability Toolkit

This repository contains an open source library that provides modelling of multi-degree-of-freedom systems and assessment via nonlinear time-history analyses for regional vulnerability and risk calculations. The vulnerability toolkit is developed by the Global Earthquake Model (GEM) Foundation and its collaborators.

Explore the docs »

View Demos · Report Bug · Request Feature

Demos



oq-vmtk / demos /

↑ Top

..		
in	Refactor slf_generator and create example	3 months ago
out/nltha	Update get_fragility_function to account distinctively for both epist...	3 months ago
README.md	Update README.md	2 months ago
example_1.ipynb	Fix bug in example_1	last month
example_2.ipynb	Fix bug in example_2	last month
example_3.ipynb	Lump examples 2 and 3 into end-to-end demonstration of cloud analysis	3 months ago

README.md

Demos

This folder contains an ensemble of example python notebooks demonstrating various steps within the GEM global vulnerability workflow highlighting earthquake catastrophe modelling and visualization techniques. Below is an overview of the four available examples:

Example 1: Ground-Motion Record Processing

This example provides a workflow for processing ground-motion records, such as spectral analysis and identification if intensity measure values for distinct intensity measure types (e.g., PGA, Arias Intensity, etc.).

Example 2: End-to-End Vulnerability Analysis of an MDOF System using Cloud Analysis

This example performs nonlinear time-history analysis on a multi-degree-of-freedom (MDOF) structural system calibrated using SDOF global capacity and using cloud analysis to assess seismic performance. The example additionally demonstrates postprocessing of cloud analysis results, including fragility curve estimation and vulnerability assessment visualization.

Example 3: Generating and Visualizing Storey Loss Functions

This example focuses on computing and visualizing storey loss functions, providing insights into seismic damage assessment and economic loss estimation.

Found an Issue? Report it!



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Vulnerability-Toolkit

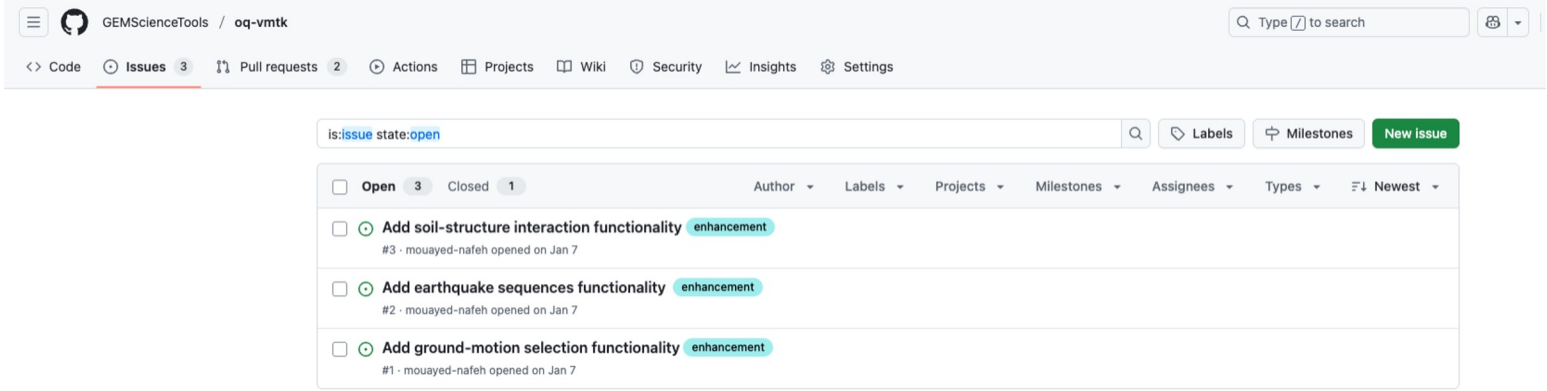
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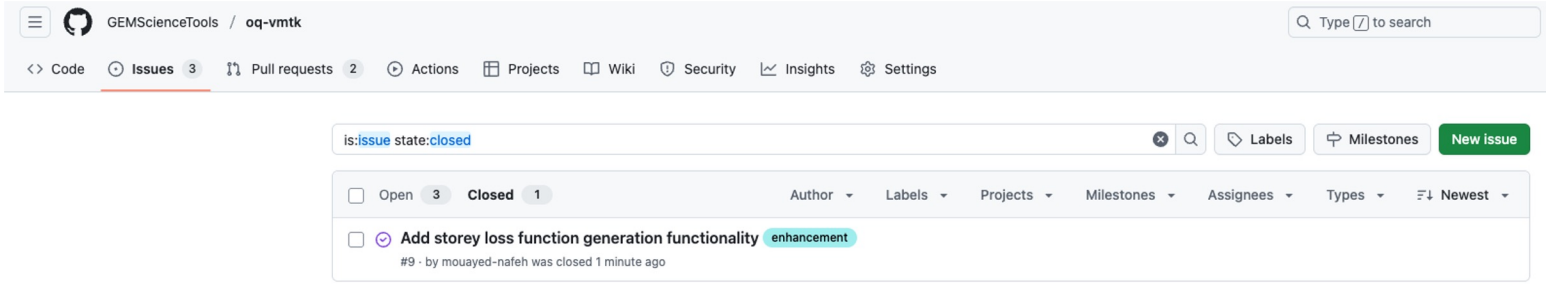
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Open Issues or Enhancements



Closed Issues

Request Features



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Vulnerability-Toolkit

Vulnerability Toolkit

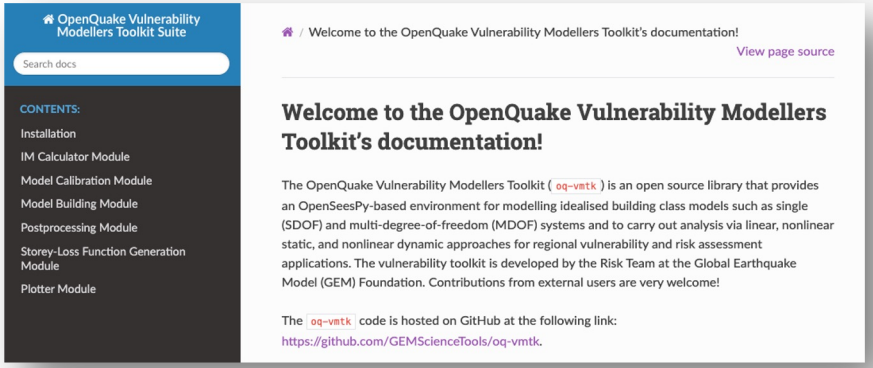
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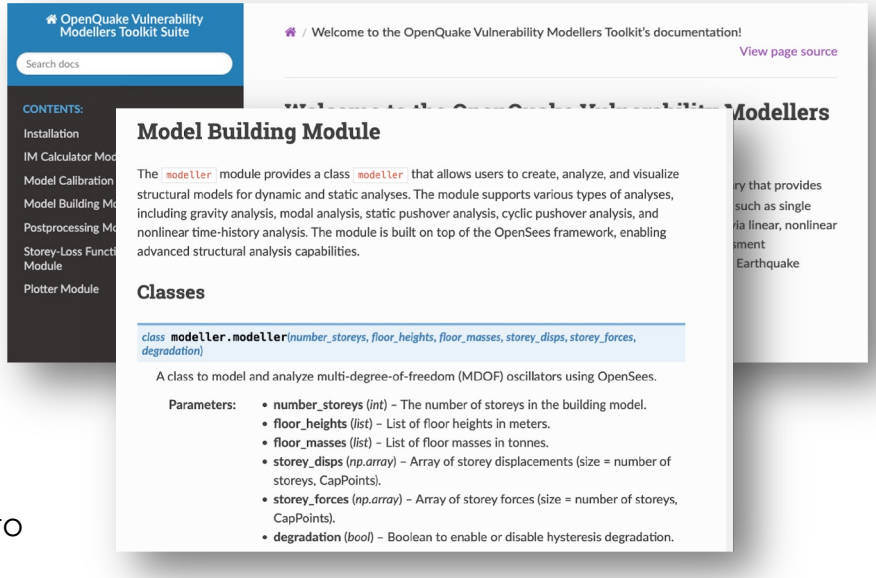
Documentation

- Dedicated documentation page hosted on https://gemsciencetools.github.io/oq-vmtk/
  - **Ensures Clarity:** Detailed instructions from installation to implementation of oq-vmtk functionalities
  - **Enhances Code Usability**: Well-documented functions, and modules make it easier for others (and future you) to understand how to use the code effectively.
  - **Encourages Community Contributions**: A well-documented project lowers the barrier to entry for external contributors, making it more inviting to participate.



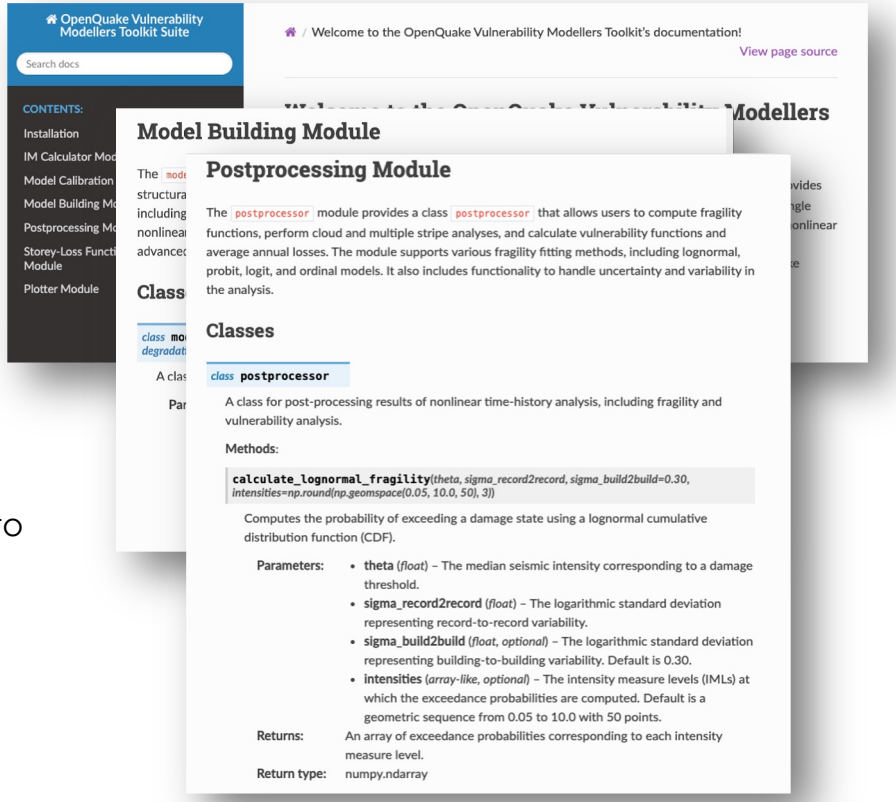
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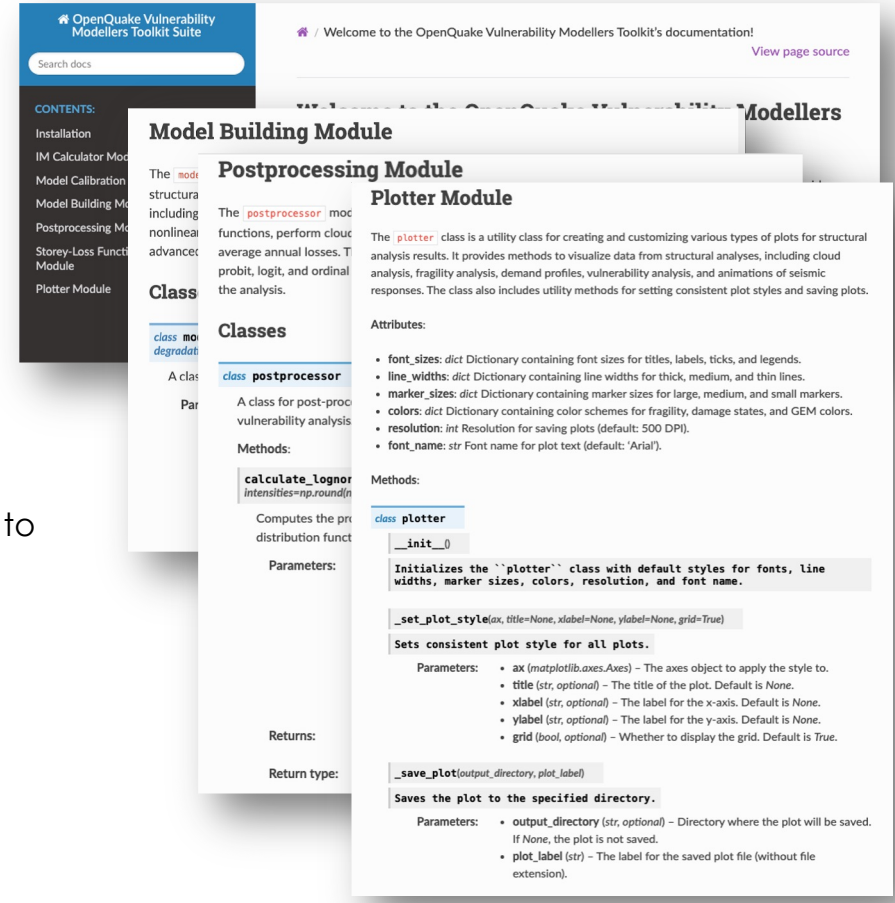
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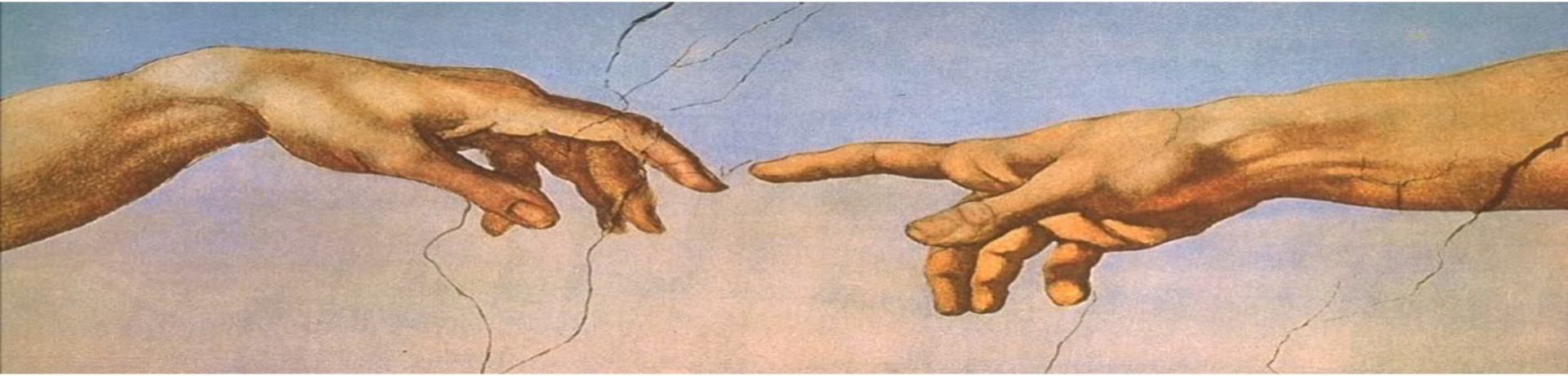


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Contribute!

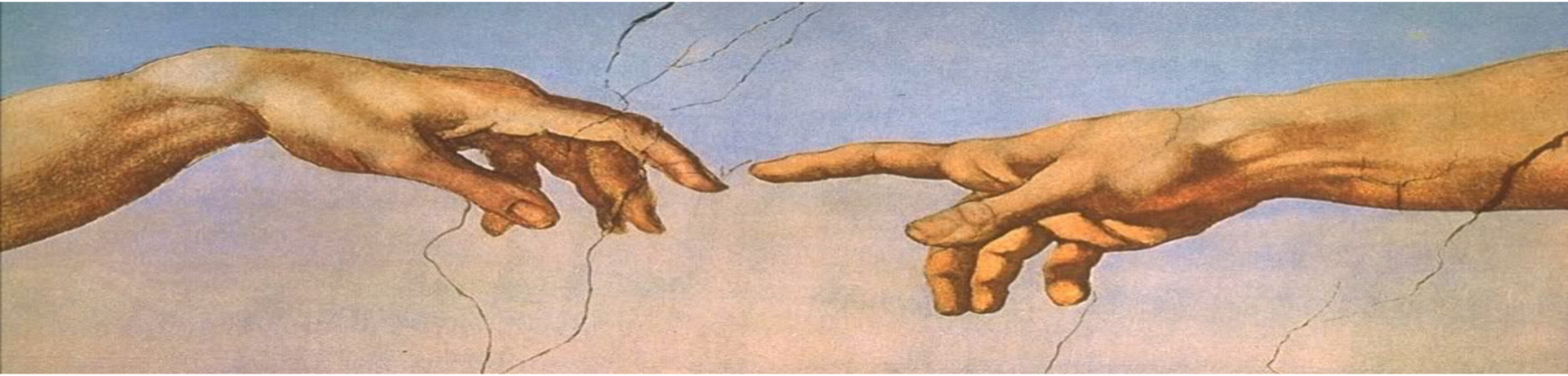


Michelangelo et al. (circa 1512)

OQ-VMTK
Stable Version



Contribute!



OQ-VMTK
Stable Version

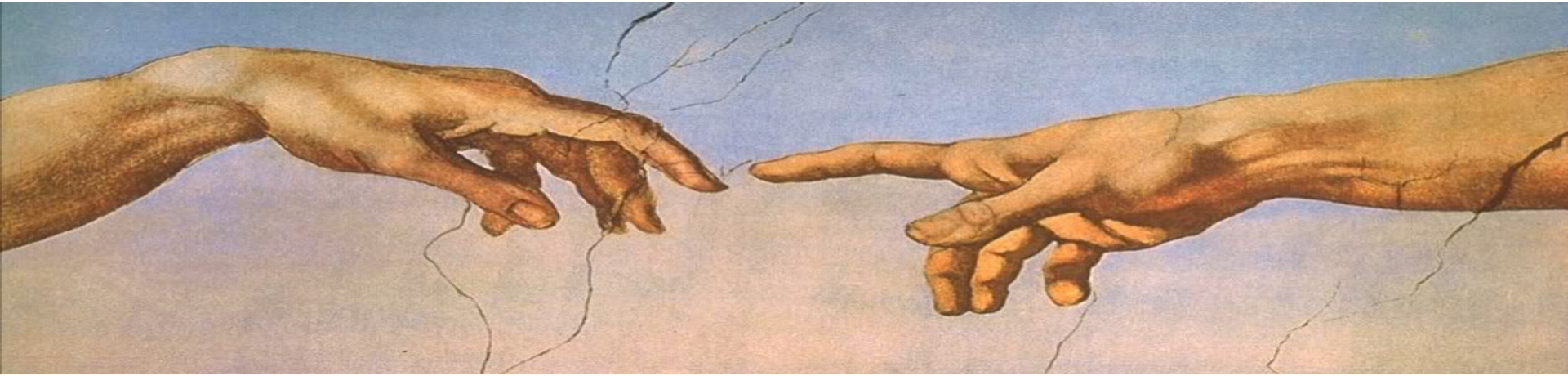
+Additional Functionalities





Ground Motion
Selection and Simulation

Contribute!



OQ-VMTK
Stable Version

+Additional Functionalities



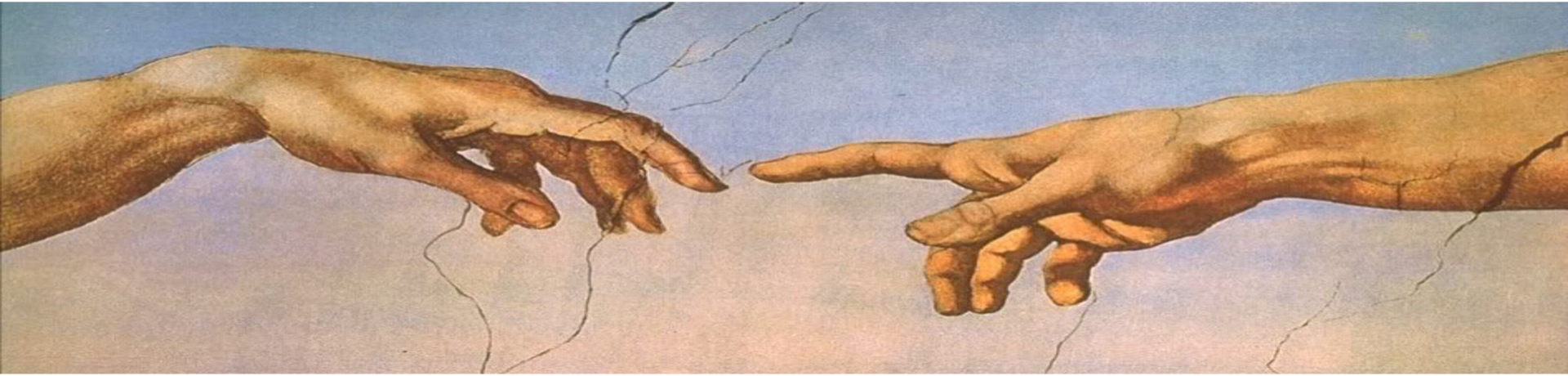


Ground Motion
Selection and Simulation



Tsunami Assessment

Contribute!



OQ-VMTK
Stable Version

+Additional Functionalities

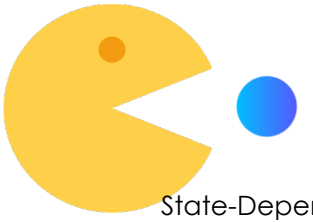




Ground Motion
Selection and Simulation

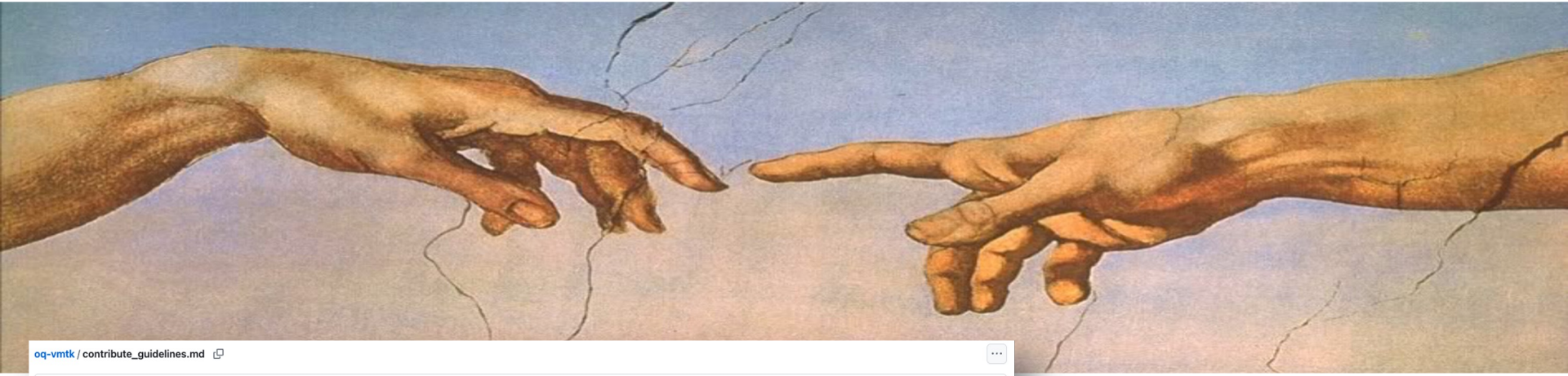


Tsunami Assessment



State-Dependence

Contribute!



oq-vmtk / contribute_guidelines.md

mouayed-nafeh Update contribute_guidelines.md — ca7c443 · 3 months ago — History

Preview | Code | Blame — 12 lines (9 loc) · 734 Bytes — Raw

🤓 CONTRIBUTE TO THE VULNERABILITY MODELLERS TOOLKIT

We welcome contributions to improve the vulnerability-modellers-toolkit (oq-vmtk) and this repository! If you'd like to contribute, follow the steps below. Otherwise, you can email your information to mouayed.nafeh@globalquakemodel.org.

1. Fork the repository on GitHub.
2. Clone your fork to your local machine.
3. Create a new branch for your feature or fix (git checkout -b feature-branch).
4. Make your changes and commit them (git commit -am 'Add new feature').
5. Push your changes to your fork (git push origin feature-branch).
6. Open a pull request on GitHub.

Please ensure that your code follows the existing style and includes relevant tests and documentation.

Contact Us

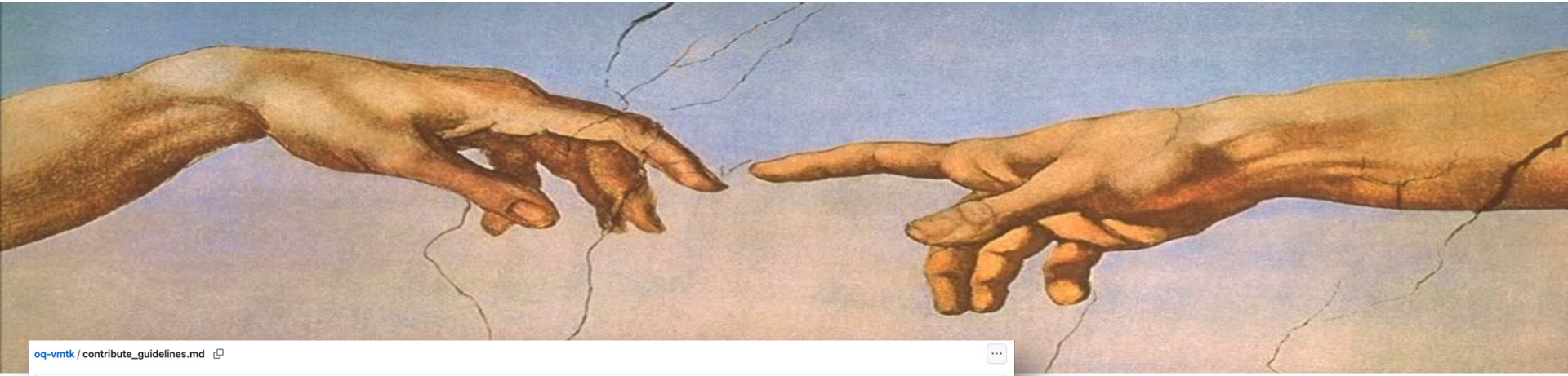


Al Mouayed Bellah Nafeh
Physical Vulnerability Lead
Lebanon



Karim Aljawhari
Physical Vulnerability Modeller
Palestine

Contribute!



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COMPDYN MS 11 - II
DEVELOPMENTS IN COMPUTATIONAL TOOLS FOR SEISMIC RISK MITIGATION

Monday
17:00 - 19:00

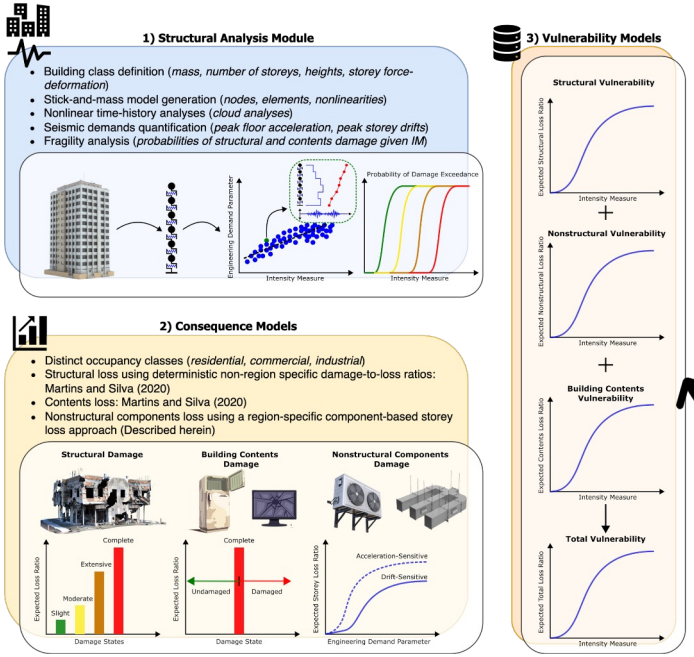
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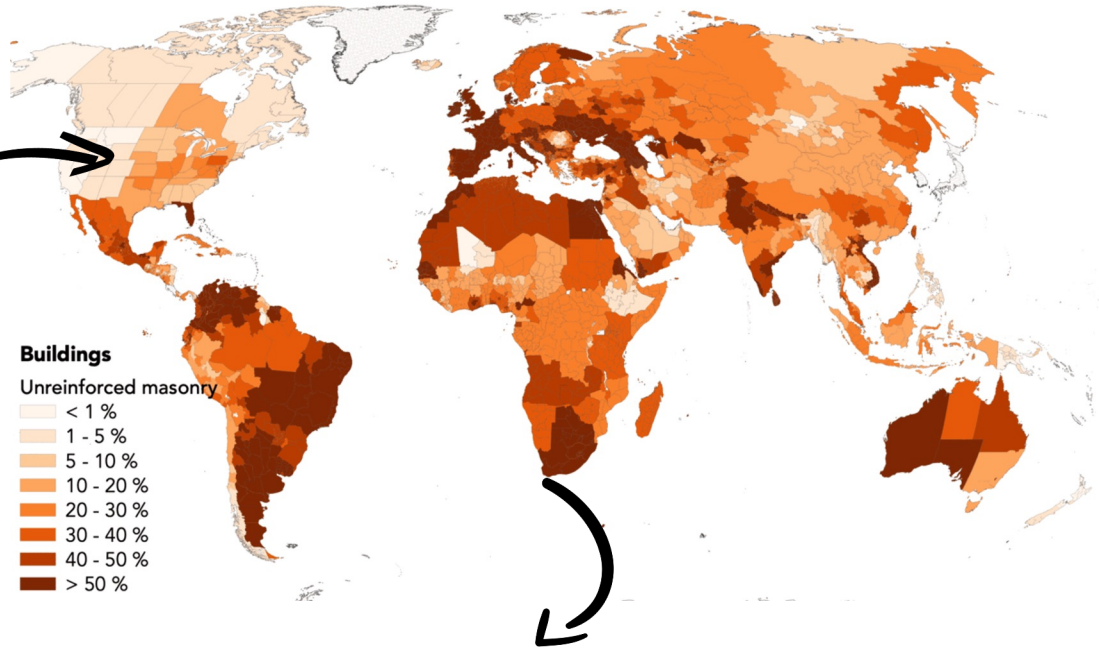
MS Organizers: *Davit Shahnazaryan, Volkan Ozsarac, Gerard J. O'Reilly*
Chair: *Volkan Ozsarac*

C 25126 DJURA GROUND MOTION RECORD SELECTOR: A SOFTWARE SOLUTION FOR EARTHQUAKE ENGINEERING
***Davit Shahnazaryan**, Volkan Ozsarac, Gerard J. O'Reilly*

C 25186 A NEW GLOBAL DATABASE OF SEISMIC VULNERABILITY MODELS FOR IMPROVED REGIONAL RISK ASSESSMENTS
***Karim Aljawhari**, Al Mouayed Bellah Nafeh, Vitor Silva*

C 26236 OPENVULNERABILITY: AN INTERACTIVE WEB PLATFORM TO SELECT AND SCORE PHYSICAL IMPACT MODELS
Roberto Gentile





Vulnerability-Toolkit

Thank you!

https://github.com/GEMScienceTools/oq-vmtk/tree/main

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