QuakeCoRE and OpenSees (Year 1): Optimisation of Source Code, Pre- and Post-Processing Tools, and Community Development

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1. Background and Objectives

The OpenSees finite element platform (**Open S**ystem for **E**arthquake **E**ngineering **S**imulation) developed through the University of California Berkeley is the principal collaborative software identified by **QuakeCoRE Technology Platform 4** for use in detailed seismic response modelling of individual infrastructure components. OpenSees was selected for this purpose due to its capabilities as an open-source platform for sequential and parallel analysis of both geotechnical and structural systems. OpenSees is one of the few tools available with all of these attributes, and due to this unique combination of features it meets all three of the underlying principles identified for QuakeCoRE Technology Platform 4: it is **open-source**, it is **scalable** (able to make use of HPC resources), and it is **flexible** (works for variety of problem types and able to work with other QuakeCoRE software modules).

The primary objectives of OpenSees development under Technology Platform 4 coincide with the overall objectives of the tech platform. These two objectives are somewhat intertwined, but specific OpenSees-related tasks/objectives are noted for each.

- **Reducing entry barriers:** As OpenSees has been adopted as the primary seismic response analysis tool for QuakeCoRE, it is important to take steps that can accelerate the process of learning and working with this tool for new researchers.
  - **Training for new users** of OpenSees to provide a headstart and build overall knowledge base of community
  - Encourage and provide arena for **community involvement** among researchers performing OpenSees analysis
- **Reducing time to solution:** It is also important to provide workflow infrastructure that reduces the pre- and post-processing overhead associated with OpenSees analysis so researchers can move from idea to analysis to results in an efficient manner.
  - Establish standardized pre- and post-processing workflows for problems identified by OpenSees user community
    - **Pre-process tools:** model generation scripts in Python and tcl (the two interpreter languages for OpenSees), standard code/script blocks to be pasted into model files, interfaces with pre-processing GUI tools such as GiD, Gmesh, etc…
    - **Post-processing tools:** Python scripts to prepare data and create common plots, interfaces with post-processing GUI tools such as GiD, Paraview, and others.

2. OpenSees Development in QuakeCoRE Year 1

To facilitate the use of the OpenSees finite element platform by QuakeCoRE researchers, several key tasks involving both human and computational resources have been identified as strategic objectives for QuakeCoRE year 1. All of these tasks fall under the overall objectives of Technology Platform 4 to reduce the entry barrier and reduce the time to solution for OpenSees researchers. To date, a number of these tasks have been completed and work is well underway on the remaining tasks.

- **User Development:** Provide a starting point for new users and enhance the capabilities of comfortable and advanced users. Encourage community engagement and provide forum for community development.
  - **OpenSees Training Workshops:** Training workshops for new to advanced users of OpenSees. Held in Christchurch on 10 and 13 June, and Auckland on 14 June. Future workshops will be held based on community feedback and interest
  - **Student Innovation Prizes:** Two $500 prizes to be awarded at the 2016 QuakeCoRE Annual Meeting recognizing significant earthquake engineering research that has been undertaken using OpenSees by postgraduate students
  - **Monthly OpenSees Community Webconferences:** To provide a place where researchers can share their work with the QuakeCoRE research community, where we can hold presentations about OpenSees topics of interest from researchers in NZ and worldwide, and to generally facilitate collaboration and sharing within the community.
- **Computational Development:** Efforts to implement and optimise OpenSees on National e-Science Infrastructure (NeSI) HPC resources, to optimise workflows for running parallel OpenSees simulations on NeSI resources, and to develop a suite of pre- and post-processing tools to streamline OpenSees use for QuakeCoRE (and all) researchers.
  - Established **development group** for ongoing development of OpenSees capability within QuakeCoRE. The group currently consists of the authors, but it is not intended to be a static group, and new members will be added as appropriate.
  - **Identification of initial tasks** for OpenSees computational development:
    - Pre- and Post-processing tools 1D site response analysis – chosen based on community feedback
    - Parallel processing workflow for very large models using OpenSeesSP – strategic objective for QuakeCoRE

3. Overview of Vision for Standardized OpenSees Analysis Workflow – Pre-processing, Analysis, Post-Processing and Visualisation

Pre-Processing Tasks for Model Generation

Code blocks for common modelling tasks

Python and tcl model creation scripts

Script converts GUI input to tcl model file

Model development using GUI tools

Ghofrani (2016)

Model Assessment and Analysis

Structural Modelling

Celarec and Dolsek. (2013)

Site Response Modelling

Jeong and Bradley (2015)

Soil-Structure Interaction Modelling

Ghofrani (2016)

Post-Processing and Visualisation

Standard plots for different problem types

Standard plotting scripts

Scripts to format output for use in GUI visualisation tools

McGann (2013)

Visualisation using GUI tools

Horizontal Displacement (cm)

northeast abutment

Ghofrani (2016)

McGann (2013)