Computational Mechanics
Department of Civil, Geo and Environmental Engineering
Technical University of Munich

Development of a Model Order Reduction (MOR) Library for an Android-Based FEM App (Pocket FEM ©)

Software Lab Project 2018

Students: Berkay Alp Cakal, Oguzhan Karakaya, Manuel Meßmer
Supervisors: Quirin Aumann, Raúl Rodríguez Sánchez

Abstract

In this project it is aimed to create a framework for FE simulations and to implement model order reduction techniques on the developed framework. Targeted hardware configurations are Android devices with ARM based CPUs. It is required to utilize benefits of MOR techniques to reduce computational cost of dynamic analysis, to avoid severe performance issues on mobile devices. Implemented FEM library is validated by solving analytical solutions of known problems together with convergence studies and comparisons to widely acknowledged FEM solvers.

Why using FEM on a Smartphone?

Use of Pocket FEM for educational purposes can be handy for quick demonstration and explanation of simple concepts like convergence, element locking and stress concentration. Moreover, such a portable computational support can provide quick insights into problems at any construction site.

FEM Package

Fully coded in C++ and integrated to Java environment with native NDK (Native Development Kit)

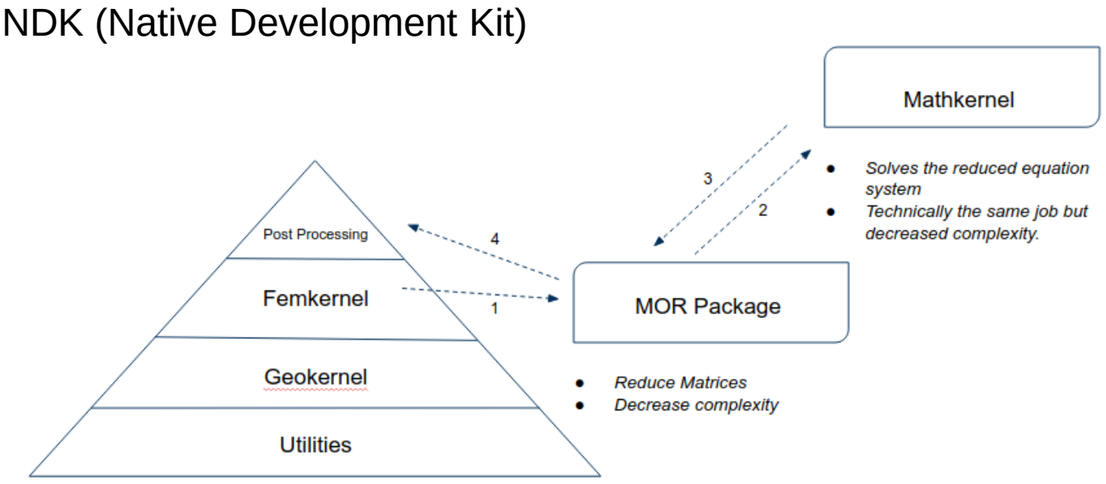


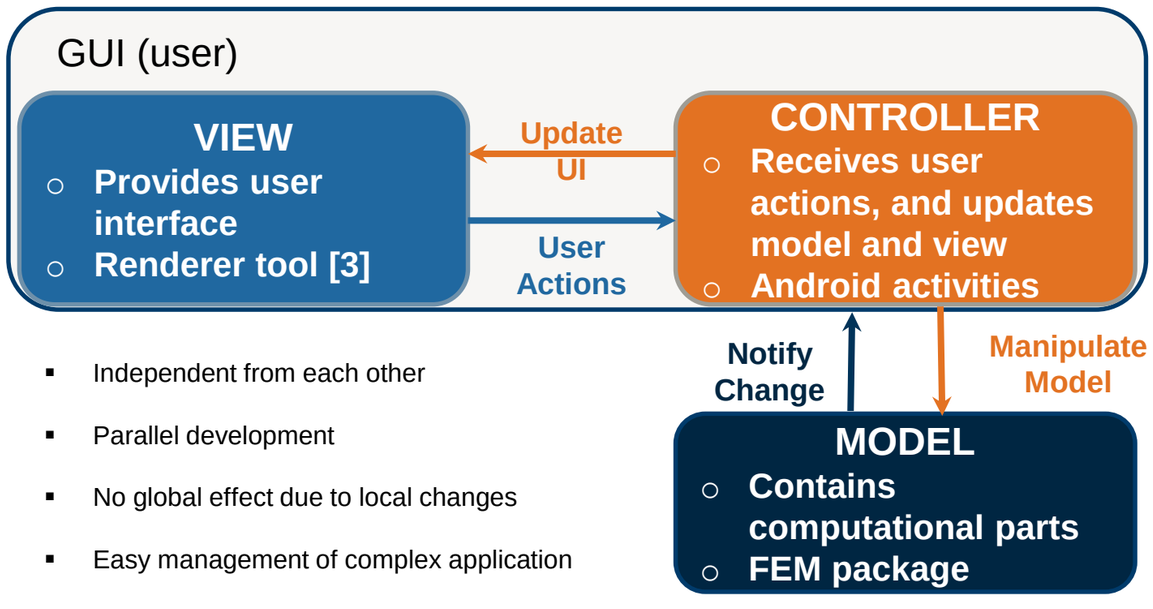
Figure 1: FEM Package Structure

Cross Platform Development

By coding FEM part in C++ and GUI part in Java and transferring data via Json-files the following outcomes are obtained:

- ✓ Enhanced control on memory management
- ✓ Faster FEM Calculations
- ✓ Cross-platform development
- ✓ Easy future implementations of FEM Package

Design Pattern: Model View Controller



- Independent from each other
- Parallel development
- No global effect due to local changes
- Easy management of complex application

Figure 2: Design Pattern: Model View Controler

Validation of the Results

To provide correct results, several validation steps were conducted based on theory as well as academic and commercial FEM solvers, e.g. Kratos, Ansys. Figure 3 compares the maximum deflection of a cantilever beam with Bernoulli Theory exemplarily.

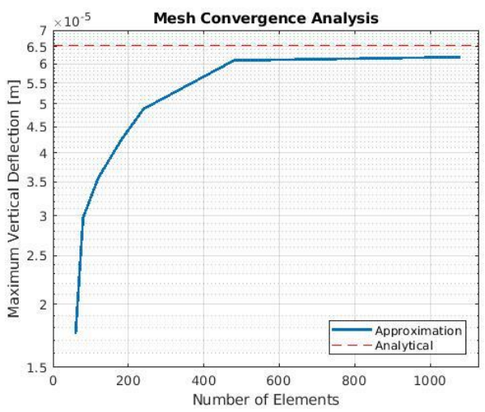


Figure 3: Mesh Convergence Analysis

Solvers

Pocket FEM consists of two different solvers. On the one hand it solves the system by inverting the stiffness matrix to obtain the static solution. On the other hand Pocket FEM can do modal analysis and visualize the frequency responses due to different excitations. [2]

Static Solution

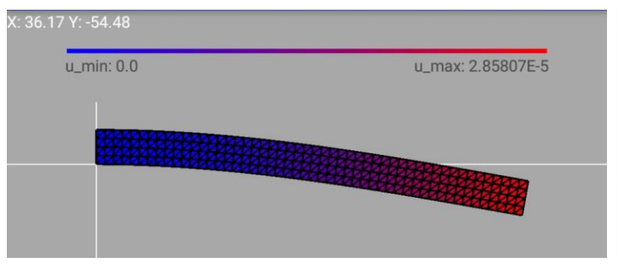


Figure 4: Screenshot Pocket FEM, Displacement Field

Dynamic Response

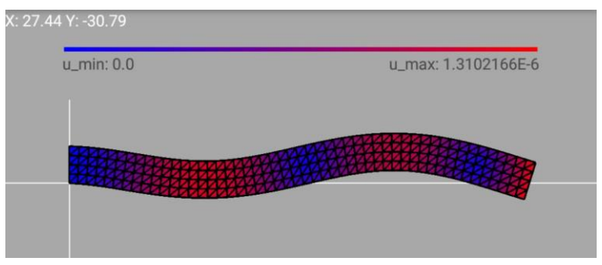


Figure 5: Screenshot Pocket FEM, 3. Eigenmode

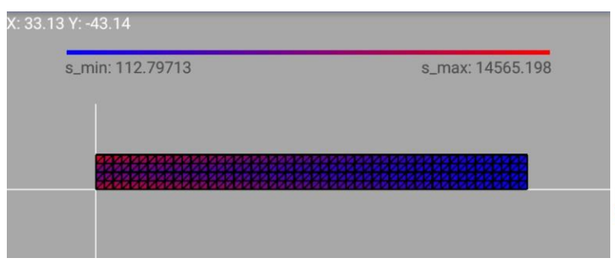


Figure 6: Screenshot Pocket FEM, Stress Field

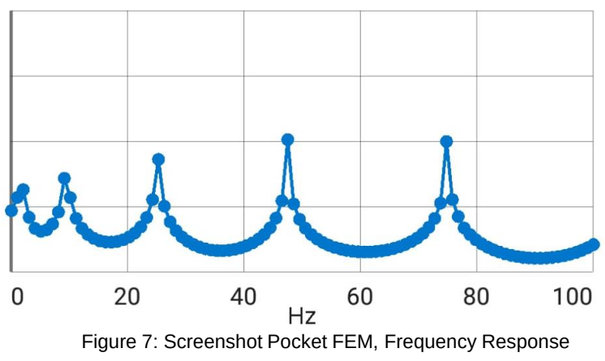


Figure 7: Screenshot Pocket FEM, Frequency Response

Model Order Reduction Method

Mode superposition method enables to obtain displacement fields for different excitation frequencies *f*. Time speed-up is significant compared to direct method, as solution field is computed by only a reduced amount of eigenvalues *n.* [1]

$$\left(\underline{\underline{K}} - \lambda\,\underline{\underline{M}}\right)\underline{x} = 0$$

$$\underline{F}_{red} = \underline{\underline{\Phi}}\,\underline{F}$$

$$\underline{u}_f = \sum_n \frac{F_{red,n}}{(\omega_n^2 - \Omega_f^2)}\,\underline{\Phi}_n$$

References:

[1] Jagmohan L. Humar: Dynamics of Structures: Second Edition. 2002, Sweets & Zeitlinger B.V., Lisse.

[2] Felippa ,C. A.: Introduction to Finite Element Methods.2004, University of Colorado at Boulder

[3] Brothaler K.: OpenGL ES 2 for Android: A Quick-Start Guide. 2013, The pragmatic programmers, LLC.