The Real ESSI Simulator System

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Outline

Introduction

Real-ESSI Simulator System

Summary
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Real-ESSI Simulator System

Summary
Motivation

Improve modeling and simulation for infrastructure objects
Expert numerical modeling and simulation tool
Reduction of modeling uncertainty
Choice of analysis level of sophistication
Goal: Predict and Inform rather than fit
Engineer needs to know!

System for modeling and simulation of Earthquakes and/or Soils and/or Structures and their Interaction:
Real-ESSI Simulator  http://real-essi.info/
Prediction under Uncertainty

- **Modeling Uncertainty**, Simplifying assumptions
  Low, medium, high sophistication modeling and simulation
  Choice of sophistication level for confidence in results

- **Parametric Uncertainty**, $M\ddot{u}_i + C\dot{u}_i + K^{ep}u_i = F(t)$,
  Uncertain mass $M$, viscous damping $C$ and stiffness $K^{ep}$
  Propagation of uncertainty in loads, $F(t)$
  Results are PDFs and CDFs for $\sigma_{ij}$, $\epsilon_{ij}$, $u_i$, $\dot{u}_i$, $\ddot{u}_i$
ESSI: Energy Input and Dissipation

Energy input, dynamic forcing

Energy dissipation outside SSI domain:
- SSI system oscillation radiation
- Reflected wave radiation

Energy dissipation/conversion inside SSI domain:
- Inelasticity of soil, contact/interface zone, structure, foundation, dissipators
- Viscous coupling with pore fluids, and external fluids

Numerical, algorithmic energy dissipation/production
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Real-ESSI Simulator System

The Real-ESSI, Realistic Modeling and Simulation of Earthquakes, Soils, Structures and their Interaction. Simulator is a software, hardware and documentation system for time domain, linear and nonlinear, elastic or inelastic, deterministic or probabilistic, 3D, finite element modeling and simulation of:

- statics and dynamics of soil,
- statics and dynamics of rock,
- statics and dynamics of structures,
- statics of soil-structure systems, and
- dynamics of earthquake-soil-structure system interaction

Used for:

- Design, linear elastic, load combinations, dimensioning
- Assessment, nonlinear/inelastic, safety margins
Real-ESSI Simulator System

- Real-ESSI System Components
  - Real-ESSI Pre-processor (gmsh/gmESSI, X2ESSI)
  - Real-ESSI Program (local, remote, cloud)
  - Real-ESSI Post-processor (Paraview/pvESSI, Python, ...)

- Real-ESSI System availability:
  - Universities: AWS, LinuxESSI image
  - Government, National Labs: AWS GovCloud, LinuxESSI image
  - Professional Practice: AWS, LinuxESSI image

- Real-ESSI Short Courses, online, worldwide

- Real ESSI Simulator system documentation at http://real-essi.info/
Real-ESSI Short Course, Fall 2019

- Online, live sessions, that are also recorded
- Weekly, 8 weeks, 3 hours per week, each Tuesdays
  - 3 hours lecture
  - Homework, practice problems
  - 3 hours discussion session
  - Message/discussion list
- October – November 2019
- Documentation, examples available online
Real ESSI Quality Assurance

- Verification, mathematics issue
  - Solution verification for each component
    - Finite elements
    - Constitutive algorithms
    - Solution advancement, static and dynamic
    - Model verification
  - Error quantification for ranges of modeling parameters
  - Automatic verification, a 13 hour process on multiple CPUs

- Validation, physics issue, partially done, in progress

- Certification process in progress
  - ASME NQA-1
  - ISO-90003-2014
Real-ESSI Modeling Features

- Solid elements, dry, (un-)saturated, elastic, inelastic
- Structural elements, beams, shells, elastic, inelastic
- Contact/interface elements, dry, coupled/saturated,
- Super element, stiffness and mass matrices
- Material models, soil, concrete, steel...
- Seismic input, 1C and 3C, deterministic or probabilistic
- Solid/Structure – Fluid interaction, full coupling
- Input programming language, requires units
- Energy dissipation calculations
- Intrusive probabilistic inelastic modeling
Real-ESSI Simulation Features

- Static loading stages
- Dynamic loading stages
- Restart, simulation tree
- Solution advancement methods/algorithms, on global and constitutive levels, with and without enforcing equilibrium
- High Performance Computing
  - Fine grained, template mataprograms, small matrix library
  - Coarse grained, distributed memory parallel
Real-ESSI Model Development

- Pre-Processing, model development gmsh/gmESSI
- Existing model translation, SASSI → Real-ESSI
- Choose level of sophistication
- Reduce modeling uncertainty
- Model developed in phases
- Verify model components
- Build confidence in inelastic modeling
Real-ESSI Modeling Phases
Real-ESSI Results Post Processing

- All output is saved (stress, strain, displacements, energy...)
- Time histories, scripts to plot or extract in preferred format
- 3D visualization, Paraview with pvESSI plugin
Real-ESSI Core Functionality

- Introduction to inelastic, nonlinear analysis for practicing engineers
- Use of prescribed, required (low, medium, high) fidelity numerical models to analyze ESSI behavior
- Set of suggested modeling and simulation parameters
- Investigate sensitivity of response to model sophistication
- Investigate sensitivity of response to model parameters
Real-ESSI Core Functionality Components

- Structural elements: Truss, Beam, Shell, Super-Element
- Soil, solids: elastic, $G/G_{max}$
- Contacts: Bonded, Frictional, Gap open/close
- Loads: Static, Dynamic (earthquake, 1C or $3 \times 1C$), restart1
- Simulation: Implicit equilibrium, Explicit no-equilibrium,
- Core Functionality Application programs: APPs
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Jeremić et al.

Real-ESSI
Summary

▶ Numerical modeling to predict and inform, rather than fit
▶ Engineer needs to know!
▶ Education and Training is the key!
▶ More info: http://real-essi.info/