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THE REAL-ESSI SIMULATOR SYSTEM, CURRENT STATUS

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ABSTRACT

Presented is the current status of the Real-ESSI Simulator system [15]. The Real-ESSI Simulator, is a system for high performance, time domain, linear and/or nonlinear/inelastic, deterministic or probabilistic, 3D, 2D or 1D, finite element modeling and simulation of earthquakes, and/or soils, and/or structures and their interaction (Real-ESSI)[1] [16, 15]. Focus of the Real-ESSI endeavor is on development and use of methods and models that predict and inform rather than fit. Detailed information about the Real ESSI Simulator system is available on Real-ESSI web site: `http://real-essi.info`.

REAL ESSI MODELING

The Real ESSI Simulator design is guided by the need for accurate modeling of earthquakes, soils, structures and their interaction (ESSI). With that in mind, a number of models, that can be used to model ESSI problems with chosen, prescribed level of fidelity, is available within Real ESSI.

Material Modeling. A number of elastic and inelastic material models are available. Elastic linear, nonlinear and micropolar models are available in 3D [7, 19, 5]. Elastic-plastic material models for soil, rock and concrete are available as well [7, 20, 22, 21, 35, 8]. Contact, interface is modeled using gap open-close models that yield in shear as well [6, 28, 36].

Finite Elements. Solids finite elements in 3D, consisting of 8, 8-20, 8-27, and 27 node bricks are available and can be combined with any of the elastic and/or elastic-plastic models above [18]. Fully and partially saturated brick elements are available for modeling fully and partially saturated soil, rock and concrete [39, 38]. Solids elements, particularly 27 node brick, can also be used to model elastic and elastic-plastic walls, plates and shells. An elastic quad shell is available [9, 2] Linear elastic and nonlinear, fiber beam elements are used for frame modeling [30, 31] Contacts, interfaces are modeled using two node force based

[1] Pronunciation of Real ESSI is similar to real easy.

and/or stress based finite elements. Stress based contact, interface finite elements feature contact, interface surface calculation. Interaction with fluid is possible by coupling of the Real ESSI with OpenFOAM.

Seismic Waves Seismic motions, waves are input using the Domain Reduction Method (DRM) [3, 37]. Wave fields necessary for DRM input can be created by one component (1C) of seismic wave field deconvolution from recorded surface motions. Input can also be created from any given signal, motions at depth or surface by deconvolution or convolution in 1C. Plane waves can also be applied in full three components, 3C, with body and surface wave present [32, 10]. In addition, output from regional scale finite difference programs, like SW4 [29, 24, 25, 23], can be used to generate DRM input for Real ESSI modeling.

Probabilistic Seismic Response. Uncertainty in material properties, elastic or elastic-plastic, and uncertainty in seismic loading can be modeled using Stochastic Elastic Plastic Finite Element Method (SEPFEM) [17, 26, 27]. Modeling using SEPFEM does solve probabilistic equation of motion intrusively in every time step, is quite accurate and efficient, and does not rely on repetitive, non-intrusive use of Monte Carlo type methods. Results are full probability density functions (PDF) for displacements, velocities, accelerations, stress and strain. Such PDFs can then be used to create cumulative density functions, fragilities, and risk calculations can follow from that.

REAL ESSI SIMULATIONS

High performance simulation within the Real ESSI rely on fine and coarse grained parallelism. Fine grained parallelism uses template meta-programs [34, 33, 1] and small matrix libraries [11]. Coarse grained parallelism uses Plastic Domain Decomposition (PDD) Method for efficient parallel simulation on multiple performance computational nodes and multiple performance inter-connectivity, networks [13, 14].

CORE FUNCTIONALITY

In order to introduce and facilitate use of the Real ESSI by the professional practice and new users, core functionality models and modeling parameters are documented. Core functionality models with pre-defined parameters comprise modulus reduction and damping models for soil (G/G_{max}), contact/interface models, structural beam and wall/plate/shell models, and other models necessary for modeling commonly modeled soil structure systems A number of examples with core functionality models and parameters are provided. In addition, simulation algorithms and simulation parameters are also recommended and presented in examples.

EDUCATION AND TRAINING

Education and training is a very important part of the Real-ESSI endeavor. On site and online short courses for practicing engineers are organized. Next online Real ESSI course will be organized in the Fall 2019.

QUALITY MANAGEMENT SYSTEM

Quality assurance (QA) effort, including extensive verification and ongoing validation (V&V), are part of Quality Management System (QMS) that is very important to create trust in numerical predictions. Numerical predictions, with adequate QMS, are used in making decisions in design, assessment and licensing of nuclear installations. The Real ESSI Simulator has gone through extensive Nuclear Quality Assurance (NQA-1) [4] effort with full documentation, and the NQA-1 certification if forthcoming.

In addition ISO/IEC 90003 [12] standard for software engineering is followed and effort fully documented.

REAL ESSI SIMULATOR AVAILABILITY

The Real-ESSI Simulator is available worldwide through Amazon Web Service (AWS). Government agencies and national laboratories (USA) use Real ESSI on AWS GovCloud region, that complies with Federal Risk and Authorization Management Program (FedRAMP). Professional practice companies can access Real-ESSI worldwide through AWS marketplace. Educational institutions can access Real-ESSI worldwide for free, using AWS educational grants. Sources for the Real ESSI Simulator system are distributed to collaborators through a special open source license.

Capabilities of Real-ESSI Simulator System will be presented through select examples, with emphasis on training and ease of use for users in professional practice and regulatory agencies. In addition, a number of papers at SMiRT-25 will present various aspects of Real-ESSI use for analysis of Nuclear Installations.

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