AGENDA

Workshop on Emerging Advances in Geomechanics- 51st US Rock Mechanics, Geomechanics Symposium

Date: Saturday, 24 June 2017, 8:00 am – 6:00 pm
Venue: The Westin St. Francis, San Francisco

Sessions	Topic	Presenter and company
Novel techniques in deep underground laboratories	Fault slip experiments in Underground Research Laboratories Insights into the couplings between permeability creation, stimulated fault area and aseismic / seismic slip	Dr. Yves Guglielmi, Lawrence Berkeley National Laboratory
	In-situ Stimulation and Circulation Experiment at the Grimsel Test Site	Dr. Reza Jalali, Swiss Federal Institute of Technology (ETH)
Field characterization	Time dependent rock mass behavior in deep hard rock mines: an inconvenient truth	Dr. Andrew Hyett, Yieldpoint Inc.
	Developing Inputs for Advanced Hydraulic Fracture Models	Dr. Robert Hurt, Pioneer Natural Resources
	Gallium Nitride: A Platform for Extreme Environment Sensors and Electronics	Dr. Debbie Senesky, Stanford University
Data analytics	Fast & Scalable Context-Aware Prototyping of Static and Dynamic Models of Subsurface Environments – A Change of Paradigm	Dr. Mario Costa Sousa, University of Calgary
	Bridging the gap between 3D Geomechanics, Modelling and Machine Learning	Dr. Stephan Arndt, Monash University
	Utilizing Advanced Analytics and Machine Learning to Optimize Productivity in Oil & Gas Operations	Dr. Mehdi Maasoumy, C3 IoT
Novel numerical techniques	An innovative, computationally-efficient simulation tool for rock fracturing applications in geomechanics	Dr. Bryan Tatone, Geomechanica Inc.
	Finite Element/Finite Volume Modeling Hydraulically Driven Fractures in 3-Dimensions	Dr. Randolph R Settgast , Lawrence Livermore National Laboratory
	Isogeometry: a step change for computational rock mechanics?	Dr. Adriana Paluszny , Imperial College

Dr. Yves Guglielmi

Dr. Mario Yves Guglielmi is Geological Staff Scientist at LBNL and is the originator of and developer of the downhole HPP tool that allows the continuous high frequency in situ monitoring of activated faults and fractures three-dimensional displacements. He has also developed the protocols for the measurement of coupled hydromechanical properties of fractures and conducted several fault activation experiments in underground research laboratoires.

Fault slip experiments in Underground Research Laboratories

Insights into the couplings between permeability creation, stimulated fault area and aseismic / seismic slip.

Abstract

Modeling Using instruments dedicated to measuring coupled pore pressures and deformations downhole, we conducted field academic experiments to characterize fault zones hydromechanical properties as a function of their multi-scale architecture, and to monitor their dynamic behavior during the earthquake nucleation process. We show experiments where different fault zones geologies under contrasted state of stresses were explored in three different underground research laboratories (IRSN-Tournemire-France, LSBB-Apt-France, Mt-Terri-Ste-Ursanne-Switzerland) where experimental conditions can be optimized. Experiments consisted in pressurizing intervals in different fault zone facies (core, fractured damage zone, etc.) to induce changes in effective stresses high enough to produce measurable fault movements. Shear and normal displacements respectively of 0.05 to 1.5 10-3m were measured at velocities of 0.1 to 10 micrometer per seconds.
Key results of these experiments is to highlight how important the aseismic fault activation is compared to the induced seismicity, and a similarity in the way faults of contrasted geologies activate under effective stress variations. We show that about 80% of the fault kinematic moment is aseismic and discuss the complex associated fault friction coefficient variations by analyzing the way large slip surfaces are invaded by fluids, and through the comparison between laboratory and field estimated friction. We identify that the slip stability and the slip velocity are mainly controlled by the rate of the permeability/porosity increase, and discuss the condition for slip nucleation leading to seismic instability.

Contact:
yguglielmi@lbl.gov
phone (510) 529 9801

Dr. Mohammadreza (Reza) Jalali

Dr. Mohammadreza (Reza) Jalali is a research scientist at Swiss Federal Institute of Technology (ETH) in Zurich. He received a BSc degree in Mining Engineering in 2004 and MSc in Petroleum Engineering in 2007, both from University of Tehran, Iran. He completed his PhD degree in 2013 from University of Waterloo working on THM coupling of naturally fractured reservoirs. During 2010 and 2012, he was also working as a geomechanical engineer at Regional Technology Center (RTC) of Schlumberger in Calgary. He then moved to Switzerland and started his postdoc career in the Engineering geology group at ETH mostly working on the thermo-hydro-mechanical (THM) benchmarking of some of the existing commercial simulators in order to capture the propagation and interaction between induced and natural fractures. He joined the Swiss Competence Center for Energy Research – Supply of Electricity (SCCER-SoE) at ETH Zurich in September 2014 and since then he is working on the hydro-mechanical characterization and hydraulic stimulation of the In-situ Stimulation and Circulation (ISC) experiment at the Grimsel Test Site.

In-situ Stimulation and Circulation Experiment at the Grimsel Test Site

Abstract

The Swiss government has decided to phase out nuclear power production by 2034 and transition to electricity production by alternatives such as hydro-power plants and enhanced geothermal systems (EGS). In this context, the newly-founded Swiss Competence Center for Energy Research – Supply of Electricity (SCCER-SoE) is conducting various types of research and development. As a part of the ongoing research, a decameter hydraulic stimulation experiment, called In-situ Stimulation and Circulation (ISC), has been initiated at the Grimsel Test Site (GTS). The main objectives of this experiment are to study and explore

- Fundamental process involved during large volume fluid injection at high pressure to create an efficient and sustainable heat exchanger in hot reservoirs at depth below 3 km,
- Spatio-temporal characterization of induced seismicity such as relative size distribution, stress drop, the relevance of static and dynamic stress transfer as fault reactivation mechanism and the decay rate of activity
- Various injection protocols with the potential to mitigate seismicity below an acceptable threshold
- Novel monitoring and imaging techniques for pressure, temperature, stress, strain and displacement as well as geophysical methods such as ground penetration radar (GPR), passive and active seismic

ISC experiment is split into four phases, pre-stimulation, stimulation, post-stimulation and circulation phases, which each phase includes planning and performing of intense field investigation followed by data analysis that guides design of the subsequent phase (Figure 1).

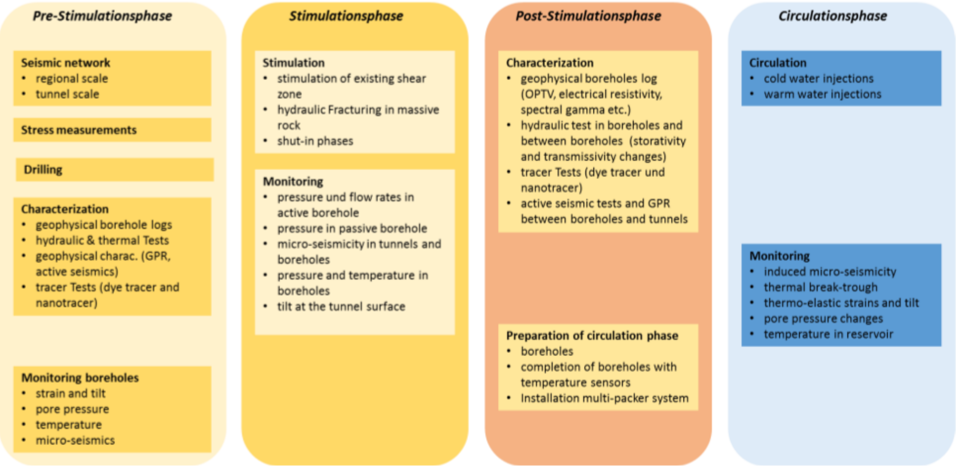

Figure 1. Four sequential phases of the ISC experiment

The ISC experiment is designed such that stimulation processes, i.e. shear dilatancy, seismic and aseismic slip front propagation, and the resulting enhancement of the fracture conductivity, are recorded in a unique interdisciplinary dataset. The data will include information on THM coupled processes and induced seismicity that could not be obtained from stimulation experiments in deep reservoirs typically targeted for EGS. This dataset also allows us to address the objectives as well as validation and verification of the existing THM and induced seismicity models.

Dr. Andrew Hyett

Dr. Andrew Hyett received his PhD in 1990 from the Royal School of Mines Imperial College, London. While at Queens University, Kingston, he invented the SMART cable bolt and co-founded Mine Design Technologies Inc. On leaving MDT in 2000 he founded YieldPoint Inc. to offer smarter and more reliable geotechnical instruments using better sensing and digital technology. 15 years later he is still motivated by the opportunities for innovation in geotechnical monitoring.

Time dependent rock mass behavior in deep hard rock mines: an inconvenient truth.

Abstract

Efficiently designed underground excavations in mines are supposed to remain safely accessible during their planned service life. Particularly for deeper mines the support systems employed to reinforce excavation walls are insufficient to prevent progressive time dependent excavation convergence: indeed attempts to do so would be (i) economically unjustifiable, and (ii) geotechnically inadvisable since the energy stored has the potential to be released violently. Practitioners have come to realize that the ground must be allowed to converge in a controlled manner so that the excavation can be managed over time as the mining proceeds; a philosophy that is quite different to that for shallower civil engineering excavations where the objective is to absolutely prevent time dependent excavation convergence. In other words, “time” is the very essence of economically optimized excavations in deep mines. Recent advances in borehole extensometer technology, in particular those using on-board digital signal processing, have improved resolution and accuracy so that sub-mm elastic movements associated with individual blasts can reliably be distinguished. Additionally, low cost data logging and telemetry technologies enable measurements to be collected at regular time intervals which further empower engineers to monitor the cause-and-effect between mining activity and ground movements. Whereas such observations promote much greater confidence in validity of the measurement dataset, they expose serious limitations in the numerical models which are being used to simulate rock mass displacement. In many cases, and especially as the rock mass surrounding the excavation becomes progressively more damaged, the displacements directly associated with blasting events are smaller than the aggregate of those occurring time-dependently between scheduled mining events. From a temporal perspective, only a fraction of the total ground movement corresponds directly with the driving mechanism: namely an instantaneous change in excavation geometry that induces stress redistribution that in turn drives movement. For convenience, rock mechanics engineers in deep hard rock mines, unable to use a feedback loop between deterministic geomechanical models and rock performance monitoring, usually resort to design strategies based on empirical models. As a result, demonstrating the ‘value’ of rock performance monitoring projects can be challenging, so dampening enthusiasm for investments in more rock performance monitoring, which simply perpetuates the problem. In this talk we examine both the geological rock physics and fundamental rock mechanics literature pertaining to time-dependency. We use this knowledge base to develop a methodology to interpret displacement measurements obtained using borehole extensometers from deep hard rock mines. Specifically we present a new framework for the interpretation of time-dependent deformation in deep hard rock mines, and introduce the application of “time series analytics” to extensometer data. Finally, we discuss whether such datasets can be used to “train” numerical models, potentially in real time, in order to enable those models to forecast excavation performance.

Contact:
Andrew Hyett
Yieldpoint Inc.
1407 John Counter Blvd, Unit 170
Kingston, ON K7K 6A9 ,Canada

Dr. Robert S Hurt

Dr. Robert Hurt received his PhD, in Civil Engineering from Georgia Institute of Technology. He specializes in engineering and analysis of hydraulic fracturing treatments and advanced topics in rock mechanics. In his current role, with Pioneer Natural Resources he advises on various topics of hydraulic fracturing and geomechanics. His previous roles with Baker Hughes included Senior Applied Engineer, Technical Director and Geomechanics Group Manager.

Developing Inputs for Advanced Hydraulic Fracture Models

Abstract

Researchers continue to make great strides in developing advanced 3D numerical models for the design and appraisal of hydraulic fracturing treatments. Yet, as the sophistication of these models continues to rise, the ability to populate them with representative input parameters has become progressively difficult. Deriving model inputs often involves up-scaling and/or smoothing of available data. If not cautious, this process will reduce the model's usefulness or possibly lead to erroneous results. This has profound impacts on the viability of these numerical tools to provide useful predictive capabilities. Development of robust and quantitative model inputs is required to enhance a 3D hydraulic fracture model's utility, increasing the models inherent value proposition. Fortunately, techniques that couple advanced field characterization with numerical tools can be quite useful in developing reliable full scale model inputs. In this talk, I will review some of the challenges in developing modeling inputs in the context of field scale applications. I will also present examples of how reduced order models, scaling, and effective parameters can be leveraged to derive 3D numerical model inputs.

Contact:
Robert S Hurt, Ph.D. Staff Engineer, Geomechanics; Pioneer Natural Resources
robert.hurt@pxd.com

Prof. Debbie G. Senesky

Dr. Debbie G. Senesky is an Assistant Professor at Stanford University in the Aeronautics and Astronautics Department and by courtesy, the Electrical Engineering Department. She received the B.S. degree (2001) in mechanical engineering from the University of Southern California. She received the M.S. degree (2004) and Ph.D. degree (2007) in mechanical engineering from the University of California, Berkeley. She has also held positions at GE Sensing (formerly known as NovaSensor), GE Global Research Center, and Hewlett Packard. She currently serves as co-editor of IEEE Electron Device Letters (IEEE EDL) and Sensors (Journal). Her current research interests include the development of micro- and nano-scale sensors, wide bandgap electronics, and interface materials for operation within extreme harsh environments. In recognition of her research, she received the NASA Early Faculty Career Award in 2012.

Gallium Nitride: A Platform for Extreme Environment Sensors and Electronics

Abstract

Harsh environment sensors and electronics can be used to perform real-time, in-situ combustion monitoring leading to designs of power and propulsion systems (e.g. industrial gas turbines, and aircraft engines) with increased efficiencies, fuel flexibility and reduced CO_2 emissions. In addition, new milestones in oil and gas, geothermal, and space exploration can be realized through the development of high temperature, radiation-hardened materials, instrumentation, and energy conversion devices. Gallium nitride (GaN) is a ceramic, semiconductor material that is inherently stable in high temperature, high radiation, and chemically corrosive environments. Recently, this material platform has been utilized to realize sensors and electronics for operation under extreme conditions. In this seminar, a review of the advancements in GaN manufacturing technology such as the growth of GaN epitaxial thin films, nanostructured interface materials (graphene and atomic layer deposited films) to GaN and high-temperature metallization to GaN is presented. In addition, the compelling results of operating GaN microsystem electronics (pressure sensors, UV detectors, resonators, and transistors) and materials within cryogenic temperatures (as low as -180°C), high temperatures (up to 600°C), and radiation-rich environments are shown. The seminar will close with future directions for GaN electronics technology, which include the development of wireless telemetry platforms and multifunctional sensor platforms for autonomous data collection within prohibitive environments.

Contact:
Prof. Debbie G. Senesky
Aeronautics and Astronautics Department
Electrical Engineering Department by Courtesy
EXtreme Environment Microsystems Laboratory
(XLab)
Stanford University

Dr. Mario Costa Sousa

Dr. Mario Costa Sousa is an Associate Professor of Computer Science at the University of Calgary, Canada. He leads the illustrates research group, a multi-disciplinary team of researchers and developers working on fundamental research of interactive modeling, visualization & analytics, applied to geosciences and engineering problems. Dr. Costa Sousa received his PhD from the University of Alberta, Canada in 1999 and his MSc from PUC-Rio, Brazil, in 1994, both degrees in Computer Science with specializations in computer graphics and visualization. His research interests include sketch-based interfaces and modeling, non-photorealistic rendering, scientific & engineering visualization, illustrative visualization, visual analytics, and multi-surface interaction design. Dr. Costa Sousa holds an NSERC/AITF/Foundation CMG Industry Research Chair in Scalable Reservoir Visualization. He is the co-author of two books, Computer Graphics: Theory and Practice, and Design and Implementation of 3D Graphics Systems (J. Gomes, L. Velho, M.C. Sousa, CRC Press, 2012).

Fast & Scalable Context-Aware Prototyping of Static and Dynamic Models of Subsurface Environments – A Change of Paradigm

Abstract

Modeling subsurface environments is very challenging, with static and dynamic heterogeneities that need to be captured, visualized and analyzed at multiple scales and depth ranges. The primary limitation in current subsurface modeling workflows is the lack of a computational framework, methodology and software environment to support fast and scalable interactive visual prototyping of these heterogeneities. This framework should enable the mapping of four types of contextual information found in varying degrees at different stages of the subsurface design & modeling pipeline. (1) The amount of data available (if any). (2) The level of uncertainty. (3) The interactive modeling, visualization and analytics goals (i.e., from “big picture” towards ‘details’). (4) The different types of users involved in the process. It should also support a set of integrated modeling & visualization techniques linking static and dynamic characterizations of the subsurface model from macro-scales to micro-scales (and vice-versa), in a seamless fashion.

In this lecture, I motivate discussions on the main factors impacting the effectiveness of multi-scale static and dynamic descriptions of subsurface data and examine opportunities for improvement and requirements for next-generation software tools. I will present a new paradigm and framework for interactive modeling, visualization, and analytics that allow such prototyping and complements existing workflows. This new computational framework is being developed by my group in collaboration with geoscientists and reservoir engineers from both industry and academia, and it is organized into three main interrelated components. (A) Sketch-based modeling techniques, enabling a more natural, faster, modeling of 3D subsurface models. (B) Integrated visualization & analytics of 3D and high-dimensional, multi-variate static and dynamic subsurface data. (C) Interaction techniques & technologies suiting specific modeling, visualization, and analytics goals and tasks (e.g., collaborative, remote interactions). Each of the three components has capabilities for capturing, structuring, and mapping the contextual information. I will also present the application of this new paradigm and software tools for different scenarios and demonstration examples.

Contact:
Mario Costa Sousa
Department of Computer Science
ICT 602
University of Calgary
2500 University Drive NW
Calgary, Alberta T2N 1N4, Canada

Dr. A/Prof. Stephan Arndt

Dr. Stephan Arndt is Associate Professor and Deputy Director for Resources Engineering at Monash University. He joined academia from an industry experience background, most recently as Baker Hughes' Regional Advisor for 3D Geomechanics in Middle East Asia Pacific. Previous roles include Manager for 3D Geomechanics in Coffey Mining and as Director of his own company, successfully brining innovative technology into the natural resources sector. With more than 20 years' experience in advanced 3D simulation methods and a focus on non-linear finite element analysis in geomechanics, he has worked in applications of rock mechanics, discrete fracture networks, coupled multi-physics simulations and constitutive models and holds a Ph.D. in Fracture Mechanics from Otto-von-Guericke University Magdeburg, Germany.

Bridging the gap between 3D Geomechanics, Modelling and Machine Learning

Abstract

The advances in computer performance, often quoted in publications, which allow us to analyze large 3D geomechanical models for applications in mass mining technologies, oil & gas reservoirs or hydraulic fracturing have not delivered the expected step change in value, fast turnaround time or scalability that was expected. Worse, each industry is weighted down by their own history and cycles of innovative breakthroughs, software development, established habits, shifting market balances and repeated resources booms, together with a gap between generations of users.

A genuine disruption of the maladroit and slow workflows that are still a reality for a large community of engineers and researchers is needed to bring us up to speed with the computers. Other industries, such as Aerospace and Automotive, keep demonstrating elegant concepts for engineering design but resources engineering has specific challenges to deal with, from highly variable materials, uncertainty in sampling, lack of access for direct measurements or obtaining physical specimen and scale effects across several magnitudes. With data collection at mine sites now exceeding terabytes each day, data science has been embraced to gain insight and considerable results have been demonstrated. The counterpart development in 3D geomechanics has been in the increase of amounts of computed data, generated in finely gridded 3D models often containing tens of millions of points, where the process of results interpretation by the user only significantly limits possibilities. Linking these two disciplines provides many opportunities and this is one focus of research in Resources Engineering at Monash University, including methods to automate model construction, scalability of modelling methods, integrating machine learning for parameter estimation, quantification of risk under uncertainty, visualization and virtual reality, and decision making based on modelling.

The example application for this talk is cave mining, a technology presenting all the challenges mentioned above and known for its specific risk profile of high upfront investments and delayed response to mine planning decisions. Fully coupled models linking draw schedule, flow modelling and geomechanics, technically demonstrated in case studies recent years, can be used for optimization and risk analysis once workflows are fully automated. Examples on the progress of this work will be shown.

Contact:
A/Prof Stephan Arndt
Deputy Director Resources Engineering, Monash University
Building 60, Room 154, 23 College Walk, Clayton Campus VIC 3800, Australia
T: +61 3 9905 4981
E: Stephan.Arndt@monash.edu

Dr. Mehdi Maasoumy

Dr. Mehdi Maasoumy is a Senior Data Scientist at C3 IoT with extensive knowledge and experience in developing machine learning algorithms for Internet of Things (IoT) applications, including predictive maintenance, anomaly detection and well output forecasting for oil and gas industry, predictive maintenance for transmission an distribution assets, revenue protection and fraud detection, load forecasting, energy disaggregation, and customer segmentation and targeting, for the smart grid industry. Mehdi received his PhD from University of California at Berkeley in 2013. His research interests include Machine Learning, Stochastic Optimization, and Model Predictive Control applied to Cyber-Physical Systems (CPS), such as energy systems and smart manufacturing. He has authored more than 30 peer-reviewed conference and journal papers and two book chapters in the area of optimal control and machine learning applied to CPS. His academic and industrial research has won several awards. He won the Best Student Paper Award at the International Conference on Cyber-Physical Systems (ICCPS 2013), Best Student Paper Award at the ASME Dynamic Systems and Control Conference (DSCC 2013), and Best Student Paper Award at the IEEE American Control Conference (ACC 2014). He received the Award of Excellence for outstanding performance in the Global Energy Forecasting Competition (GEFCom) 2014 from the IEEE Power & Energy Society. He serves on the technical program committee of IEEE Green Energy and Systems Conference (IGESC), and IEEE Silicon Valley Computer Society).

Utilizing Advanced Analytics and Machine Learning to Optimize Productivity in Oil & Gas Operations

Abstract

The oil and gas industry, like many other industries, is experiencing an increase in the number of sensors and devices installed in fields and pipelines. In the past few years, the availability of new technology based on commodity hardware has made it possible to process large volumes of various types of data at much higher rates than conventional technology. The rapid progress of these technologies, including elastic cloud computing, instrumenting of value chains, big data, and machine learning, offers oil and gas companies the chance to solve previously unsolved questions and automate high-cost, dangerous, or error-prone tasks. This results in improved efficiency and reduced operating costs.

We integrate disparate data sources – such as daily sensor readings from in-field equipment, unstructured data (e.g., field notes, operator comments, and maintenance logs from maintenance work orders), production logs, well attributes, and seismic survey data – to create a unified federated data image. This comprehensive data integration and tools in the C3 IoT Platform give data scientists the capability to rapidly iterate and refine machine learning models and deploy them to production in real time.

In this talk, we will demonstrate successful deployments of C3 Predictive Maintenance and C3 Well Output Forecasting for the Oil and Gas industry. In the Predictive Maintenance problem, we employ machine learning-based algorithms such as multi-class classification and regression models to predict equipment failure in terms of lifetime or “mean time to failure” (MTTF), to improve condition-based maintenance. We show how to identify the key design and operating parameters affecting the performance and failure of individual wells, to understand and then extend their lifetime going forward. In the Well Output Forecasting problem, we use multi-class classification techniques and show how to identify the key predictors of output from individual gas wells and predict well output (low, medium and high) in different stages of well lifecycle such as planning, drilling, completion and early production. We identified the factors that best predict output from an individual well and validated the levers to pull to optimize the output from a well or a field. For both problems, we present a thorough comparison of the results obtained from various supervised-learning techniques.

Dr. Bryan S.A. Tatone

Dr. Bryan joined Geomechanica as an NSERC Industrial R&D fellow in October 2014 following completion of a Post-doctoral fellowship at Queen's University. He holds a BASc degree in Geological Engineering (Waterloo, '07) and MASc and PhD degrees in Civil Engineering (Toronto, '09, '14). His area of expertise is rock discontinuity roughness and shear behaviour, which he has studied both experimentally via micro-CT imaging and numerically via the application of hybrid continuum-discontinuum numerical methods. He currently manages Geomechanica's rock mechanics laboratory.

An innovative, computationally-efficient simulation tool for rock fracturing applications in geomechanics

Abstract

In recent years, there has been a fast growing interest in the development, validation, and application of numerical simulation tools that can realistically capture the progressive nature of rock mass failure in response to mechanical, hydraulic, and thermal loading. Among different approaches, the finite-discrete element method (FDEM) has emerged as a promising technique to explicitly simulate brittle fracture and fragmentation processes in discontinuous rocks. However, due to its excessive computational demand the method has been mostly limited to date to small (or medium scale), two-dimensional (2D) analyses. To overcome this limitation, an innovative FDEM-based simulation software has been developed by Geomechanica Inc. The approach takes advantage of the computational power of modern graphics processing units (gaming or professional GPUs) using innovative high performance computing (HPC) and parallelization techniques.

In this talk, the physical principles at the basis of the 2D/3D modelling technique will be first introduced, including the algorithms used to model rock fracture, elastic deformation and fluid flow. An overview of software verification and validation efforts will be also provided. Key computational aspects of the GPU software implementation will then be highlighted. Capabilities of the software will be illustrated through a series of application examples from the civil engineering, oil & gas, and mining industries. These simulation cases include the assessment of excavation damaged zone around underground excavations, simulation of the geomechanical response of discontinuous reservoirs subjected to fluid injection, and analysis of structurally-controlled rock mass failure in large open pit mines. Both 2D and 3D simulation results will be presented. Finally, the computational performances and speedups will be discussed by analyzing the results of a benchmarking study against equivalent CPU-based software.

Contact:
Dr. Bryan S.A. Tatone
Geomechanica Inc.
390 Bay St., Suite 900
Toronto ON, M5H 2Y2, Canada
bryan.tatone@geomechanica.com
Tel: +1 647 478 9767
Cell: +1 905 870 8930

Dr. Randolph R Settgast

Dr. Randolph Settgast is a senior member of the technical staff at Lawrence Livermore National Laboratory. Dr. Settgast received his Ph.D. from the University of California, Davis in 2006, and has been at LLNL for most his professional career. He has primarily been focused on issues pertaining to the numerical simulation of physics/engineering problems at large computing scales. He is the originator/primary author of the GEOS simulation framework which has been applied successfully to simulate hydraulic fracturing at field scales. He currently serves as the architect and lead developer of the GEOS effort, and is driving development towards portability to next generation (exascale) computing platforms.

Finite Element/Finite Volume Modeling Hydraulically Driven Fractures in 3-Dimensions

Randolph R Settgast, Joshua A. White, Pengcheng Fu,

Chandrasekhar Annavarapu, Chris Sherman, Fredrick J. Ryerson, Joseph P. Morris

Abstract

This presentation will describe a fully coupled finite element/finite volume approach for simulating problems involving field-scale hydraulically driven fractures in three dimensions utilizing massively parallel computing platforms. A detailed description of the governing equations, and numerical implementation is provided, including a discussion on assumptions to ensure a well-posed problem. In particular, methods to avoid numerical issues associated with the near tip-region will be discussed. We will outline different integration strategies (explicit/implicit) for solving the fully coupled system, including a comparison of computational effort associated with the options. The challenges of handling changes in mesh topology in a massively parallel distributed-memory computing environment will be discussed.

A series of numerical studies comparing the model to both analytical solutions and experimental results will be presented. The choice of a Finite Element Method allows the proposed method to provide a reasonable representation of local heterogeneities, layering, and natural fracture networks in a reservoir. To illustrate the flexibility and effectiveness of the proposed approach when applied to real-world problems, several field scale case studies will be presented.

Contact:
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94551

Dr. Adriana Paluszny

Dr. Adriana Paluszny obtained a degree in Computational Engineering from the Universidad Simón Bolívar, Caracas, Venezuela. She then completed her PhD in Computational Geomechanics at Imperial College London in 2009, and shortly thereafter became a Post-Doctoral Research Associate in the Rio Tinto Centre for Advanced Mineral Recovery at ICL. She is currently a Research Fellow in the Department of Earth Science and Engineering at ICL, where she works on CO_2 sequestration, hydraulic fracturing in shale, rock drilling, effective permeability of fractured rocks, and emerging methods in computational fracture mechanics. She has published two dozen journal papers, and eleven ARMA/ISRM papers, on topics such as numerical modelling of fracture growth, fluid flow through fractured and porous media, and rock fragmentation.

Isogeometry: a step change for computational rock mechanics?

Abstract

Isogeometry is a novel numerical method that directly solves partial differential equations on the differential geometry of a body. It proposes a new manner of discretization, and reduces computational time, whilst increasing accuracy. Isogeometry combines geometry, discretization, and interpolation into one object, a Non-Uniform Rational B-Spline (NURBS). Control points, weights, and a set of knots describe a NURBS object. Thus, the body of a 2D object is represented by a 2D NURBS, and the body of a 3D object is represented by a 3D NURBS. The implicit parametrization of the NURBS object is utilized to discretize the body, bypassing discretization tools such as meshes or nodes, and allows users to directly interpolate and integrate properties on its parametric space. NURBS can be implicitly refined, and can be elevated in order and refinement during simulations. NURBS interpolation properties allow for local variations of functions, that may have anisotropic order (for example, linear in z and quadratic in x and y), and can be elevated in degree to accommodate continuity requirements at nodes and element edges. By merging the geometric and numerical models into one, isogeometry can achieve two orders of magnitude speed-up in computations, whilst increasing the accuracy of the solutions. These advantages have already been exploited in the fields of shells and fluid dynamics, achieving significant increases in accuracy, whilst reducing complexity and computational cost by up to two orders of magnitude. This talk will discuss how isogeometry works, how it has been applied in other fields, and how it can potentially be applied in the field of rock mechanics. Isogeometry has the potential to bring us one step closer to performing complex simulations of rock deformation and fluid flow, in real time.

Contact:
Dr. Adriana Paluszny
Research Fellow
Department of Earth Science and Engineering Imperial College London United Kingdom
Phone: +44 207 594 7435