Computational modeling and visualization in geomechanics
Vertically Integrated Program
Georgia Institute Of Technology

Dr. C. Arson
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# VIP: Computational modeling and visualization for geomechanics – Spring 2023

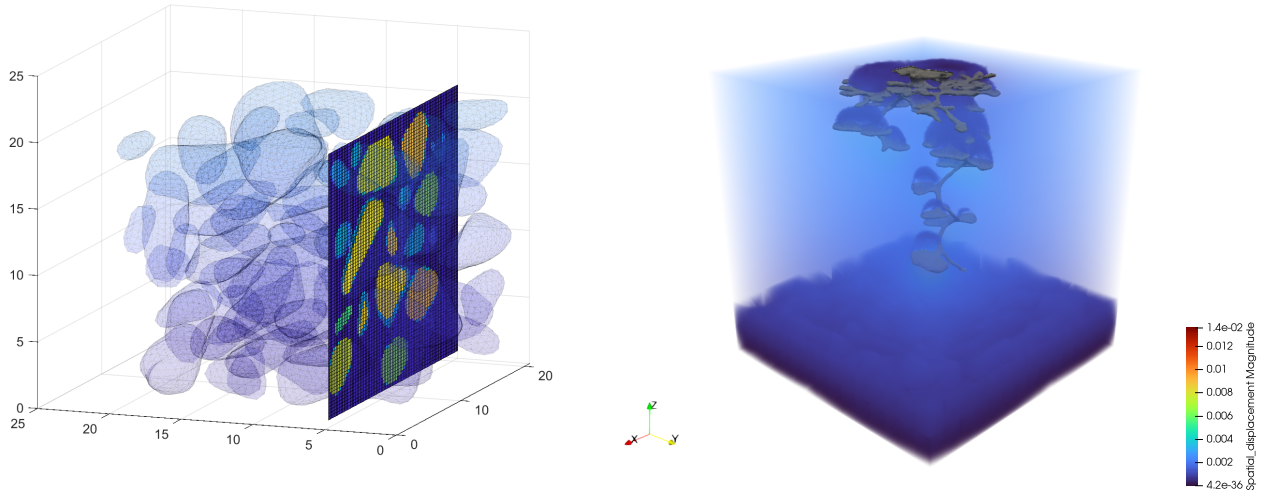
**Meeting Times:** **Fridays 9.30am-10.20am** (VIP meetings) **or 9.30am-11am** (graduate student meetings)
**Location:** **Mason 2119 except 02/24 (DEEL 303)**
**Office Hours:** By appointment

**Research Goals:** To understand the role of microstructure and fabric on the hydro-mechanical behavior of geomaterials; To model the macroscopic behavior of geomaterials from the knowledge of microscopic processes; To use Artificial Intelligence (AI) to inform and improve these models; To predict deformation, fluid flow and instabilities in geomaterials based on these AI-informed models; To simulate the effects of climate change on soils and rocks and predict landscape evolution and greenhouse gas emissions; To design self-propelled geotechnical probes inspired by burrowing organisms; To optimize the trajectory of these self-propelled probes and back-calculate soil properties from the data that they collect from sensors.

**Issues involved or addressed:** Why do rocks deform and break over time? Is it sustainable to repair cracks in geomaterials? How is the history of geomaterials encoded into microstructure and fabric? Why may rainfalls be responsible for carbon dioxide and methane emissions? Why do some underground structures collapse and others stay stable? Can nature inspire the design of burrowing machines? What data needs to be processed by an Artificial Intelligence to optimize the trajectory of a burrowing robot?

**Partners and Sponsors:** National Science Foundation (NSF), Center for Bio-Inspired and Bio-mediated Geotechnics (CBBG), Department Of Energy (DOE), Georgia Department of Transportation (GDOT).

**Methods and Technologies:** Statistical Analysis, Machine Learning, Bio-inspiration and bio-mimicry, Mechanical analysis, Finite Element Simulations, MATLAB and Python Programming.




**Preferred Interests and Preparation:** Computer Science & Engineering, Electrical Engineering: background needed in programming (Python, C++), machine learning (regression, classification, neural networks), basic knowledge recommended in numerical simulation (MATLAB and computational mechanics software). Mechanical, Civil and Environmental Engineering: background in solid mechanics required; skills and interest needed in numerical simulation (MATLAB, ABAQUS); basic knowledge of geology, mechanics of materials and/or dynamics recommended. Earth & Atmospheric Sciences: background recommended in geology, flow in porous media, geomorphology and/or geophysics, skills and interest needed in image analysis and numerical simulation

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(ImageJ, MATLAB, ABAQUS). Physics: knowledge needed in rheology; skills and interest needed in numerical simulation (MATLAB, ABAQUS).

**Damage Poro-Mechanics Laboratory Team (DeeP MeLT) members involved in Spring 2023:**

**Dr. Chloé Arson** <chloe.arson@ce.gatech.edu> - Professor, overall supervisor
**Mr. Haozhou He** <hehezid@gatech.edu> - Ph.D. candidate
**Mr. Daniel Chou** <dchou9@gatech.edu> - Ph.D. candidate
**Mr. Xiangyu (Melo) Wang** <xwang978@gatech.edu> - Ph.D. student
**Ms. Meron Belachew** <mbelachew3@gatech.edu> - Ph.D. student
**Mr. Chengwu Jiang** <chengwu.jiang@gatech.edu> – Ph.D. student
**Mr. Sanshrit Singhai** <singhai.sanshrit@gatech.edu> - M.Sc. student

**Spring 2023 research Teams and Advisors:**

Muti-scale modeling of heterogeneous media informed by Artificial Intelligence
*Leads: Daniel Chou and Chengwu Jiang*

- Deep learning strategies to detect load-induced microstructure changes in cement/aggregate mixtures
- Auto-encoders to extract the microstructure features that dominate the behavior
- Correlations between latent features and physical features
- Multi-scale permeability models enriched with physical features

Intelligent tunneling
*Leads: Meron Belachew and Sanshrit Sanghai*

- Simulation of ant-inspired tunnel burrowing strategies
- Design of a geotechnical probe self-propelled with a conveyor belt
- Back-calculation of random soil properties from stress fields
- Prediction of stress field around a burrowing robot from stress field at prior locations by AI
- Optimization of the trajectory of a self-propelled robot by AI

Prediction of plasticity in pre-stressed concrete structures by Machine Learning
*Lead: Melo Wang*

- Finite Element (FE) simulations of flexion on a pre-stressed reinforced concrete beam model.
- Program an algorithm in Python to classify beams as safe, unsafe and reparable, based on the spatial distribution of plastic strains in the FE models.

**Grading:**

Research work and documentation (50%): The grade will reflect: the relevance and feasibility of the research objectives and tasks designed in collaboration with the team advisor at the beginning of the semester, the work done to pursue/acquire any necessary knowledge/skill to meet the research objectives, the quality and clarity of the progress updates given during the team meetings, the ability to listen to and act upon the feedback given by team mates, the performance towards the semester research objectives, the quality and relevance of the research deliverables (mid-term presentation, final presentation, mid-term report, final research deliverables). ***Presentations and reports*** should summarize the background/motivation of the research, the main objectives of the semester and the methods employed to achieve these objectives. Then, results should be presented, described and interpreted. The conclusions should highlight the main take-away messages, indicate whether the

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research objectives have been met and explain the work that still needs to be done to achieve or go beyond the research goals. References should be cited according to one of the formats used by Google Scholar. Presentations should be easy to read and supported by as many graphical illustrations as possible, whereas reports are expected to contain more text. The ***mid-term report*** is a team effort and should be 5 pages long excluding cover pages, figures and references (11pt font, 1-inch margins). The nature of the ***final deliverable*** is decided at the beginning of the semester after a discussion between the VIP student and their team advisor. Final deliverables can be application packages, pieces of code with test files and users' guides, tutorials or reports. Final reports (used as final deliverables) are individual assignments of at least 7 pages (11pt font, 1-inch margins) excluding cover pages, figures and references.

Teamwork (25%): The grade will reflect timely and engaged participation to VIP meetings and sub-team meetings, contributions to the overall sub-team research goals (in addition to individual objectives) and/or assistance to other VIP members, team work coordination.

Web page (25%): Each VIP student will develop contents for Arson's group website. It is expected that each student will produce the equivalent of 500-700 words and 1-3 figures. Students will produce their contents in an editable text document that will be used to update the DeeP MeLT website, or write in HTML directly.

Final grade: F<60%≤D<70%≤C<80%≤B<90%≤A≤100%

**Tentative Agenda:** We will combine research-focused meetings led by graduate students (GRAD - 1h30) and education-focused meetings led by the VIP students and the graduate students advising them (VIP - 50 minutes). VIP students are not expected to participate in the research-focused meetings, but they are invited to attend. Graduate students who are not advising VIP students may skip the VIP meetings. The time table below is indicative and will be updated regularly.

| Date | Mtg. type | Room | Agenda |
|---|---|---|---|
| **01/13** | **GRAD** | Mason 2119 | Semester kick-off: coursework, VIP research plans, conferences |
| **01/20** | **VIP** | Mason 2119 | Semester kick-off: VIP students choose their research topic |
| **01/27** | **GRAD** | Mason 2119 | Presenter: **Chengwu Jiang** (post-comp. exam presentation) |
| **02/03** | **VIP** | Mason 2119 | Mini-course: AI in Geomechanics (**D. Chou, S. Singhai**) |
| **02/10** | **GRAD** | Mason 2119 | Presenter: **Melo Wang** (post-comp. exam presentation) |
| **02/17** | **VIP** | Mason 2119 | Mini-course: Finite Element Modeling (**X. Wang, C. Jiang**) |
| **02/24** | **GRAD** | DEEL 303 | Presenter: **Meron Belachew** |
| **03/03** | **VIP** | Mason 2119 | **Mid-term VIP project presentations**<br>Deliverables: VIP students prepare a report as a team (see the grading rubrics) and they send it to Dr. Arson, along with their presentation slides. |
| **03/10** | **GRAD** | Mason 2119 | Presenter: **Daniel Chou** |
| **03/17** | **VIP** | Mason 2119 | Debrief about mid-term presentations and progress check-in |
| **03/31** | **GRAD** | Mason 2119 | Presenter: **Sanshrit Singhai** (cumulative master's presentation) |
| **04/07** | **VIP** | Mason 2119 | Mini-course: Biomimicry (**M. Belachew**) |
| **04/14** | **GRAD** | Mason 2119 | Presenter: **Haozhou He** (Ph.D. defense rehearsal) |
| **04/21** | **VIP** | Mason 2119 | **Final VIP project presentations**<br>Deliverables: VIP students send their slides and final deliverables to Dr. Arson after the meeting (see the grading rubrics). |

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**Academic Honesty**

The main principle in VIP academic honesty is that you will not present someone else's work as your own. Use of any previous semester course materials is allowed for this course; however, it is reminded that while they may serve as examples, they are not guidelines for any projects or any other deliverable that may be assigned during the semester.

Plagiarizing is defined by Webster's as "to steal and pass off (the ideas or words of another) as one's own: use (another's production) without crediting the source." If caught plagiarizing, you will be dealt with according to the GT Academic Honor Code. Quote and attribute any words that are not your own. Do not cut and paste more than 10% of your paper; any percentage more than this will be considered plagiarism.

Additionally, to provide a good working environment for all students, you are expected to adhere to rules given here, posted, or disseminated in class. Academic Honesty is taken seriously and failure to follow these principles will result in disciplinary actions as given in the Student/Faculty Handbook.

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

**Dean of Students Office, CARE Center, Counseling Center, Stamps Health Services, and the Student Center.**

The **CARE Center** and the **Counseling Center**, Stamps Health Services, and the Dean of Students Office will offer both in-person and virtual appointments. Student Center services and operations are available on the **Student Center** website. For more information on these and other student services, contact the Dean of Students or the **Division of Student Life**.

**Information Related to Covid-19.**

Students are expected to be familiar with and abide by the Institute guidelines, information, and updates related to Covid-19. Find campus operational updates, Frequently Asked Questions, and details on campus surveillance testing and vaccine appointments on the **Tech Moving Forward site.**

**Accommodations for Students with Disabilities**

If you are a student with learning needs that require special accommodation, please contact the Office of Disability Services at (404)-894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

**Diversity Statement**

I consider the lab to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All lab members are expected to contribute to a respectful, welcoming and inclusive environment for every other lab member.

**Safe Zone Statement**

I am a member of a Safe Zone Ally community network, and I am available to listen and support you in a safe and confidential manner. As a Safe Zone Ally, I can help you connect with resources on campus to address problems you may face that interfere with your academic and social success on campus as it relates to issues surrounding sexual orientation and gender identity. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. My goal is to help you be successful and to maintain a safe and equitable campus.