Introduction inaugural ML4Seismic Parters Meeting

Felix J. Herrmann[1,2,3]

November 22, 2021

[1] Georgia Tech College of Computing, School of Computational Science and Engineering
[2] Georgia Tech College of Sciences, School of Earth and Atmospheric Sciences
[3] Georgia Tech College of Engineering, School of Electrical and Computer Engineering

SLIM
Georgia Institute of Technology

ML4Seismic

Released to public domain under Creative Commons license type BY (https://creativecommons.org/licenses/by/4.0)
Copyright (c) 2021, Felix J. Herrmann (Georgia Tech)

SLIM
ML4Seismic

Wellcome

ML4Seismic

Center for Machine Learning for Seismic Industry Partners Program is a

- public-private partnership between Georgia Institute of Technology, Oil & Gas industry & Cloud providers supported by Microsoft, Chevron, Equinor & Occidental
- collaboration between
  - Dr. Ghassan AlRegib (ECE) – Omni Lab for Intelligent Visual Engineering & Science (OLIVES)
  - Dr. Felix J. Herrmann (EAS/CSE/ECE) – Seismic Laboratory for Imaging & Modeling (SLIM)
- launched early 2020

During inaugural meeting

- report research progress & demo our open source software
- platform for feedback & discussion on future research directions

Who is here

Excited to welcome 124 registered participants

- 24 from ML4Seismic industry partners
  (Chevron, Equinor, Microsoft, Occidental)

- 100 from industry & academia
  (AWS, BGP, BHP, BP, CGG, Emerson, Extreme Scale Solutions, ExxonMobil, Haliburton, IHS Markit, ION, Osokey, Petrobras, PGS, RepsolSinopec, Saudi Aramco, Shell, Schlumberger, TGS, TotalEnergies, Woodside)

- 25 companies & several international universities

Background

Collaboration

OLIVES:

- machine learning, image processing & computer vision
- robust learning & learning w/ limited labels
- open source datasets & software for object recognition, facies classification, etc.

OLIVES
@GeorgiaTech

SLIM:

- wave-based imaging/monitoring, UQ & machine learning
- variational inference w/ normalizing flows & ML at scale
- open source datasets & software for FWI/RTM, UQ, CCS monitoring, etc.

SLIM

Responsible for driving innovations & reducing costs…

Strengths

Georgia Institute is a powerhouse in

- engineering
- machine learning

Combination OLIVES & SLIM

- complementary areas of expertise
- innovate w/i the intersection of seismic imaging/monitoring & machine learning
- train students in these areas

Transdisciplinary approach essential to navigate the energy transition…

Mission

Train next-generation of students to be well versed in

- machine learning & data science
- scientific computing
- specific domain knowledge for seismic imaging & quantitative interpretation

Seek balance between

- gaining fundamental understanding
- driving / accelerating innovations w/ tangible solutions to real problems

Recognition

Dr. Ghassan AlRegib is recognized as a world-leader in

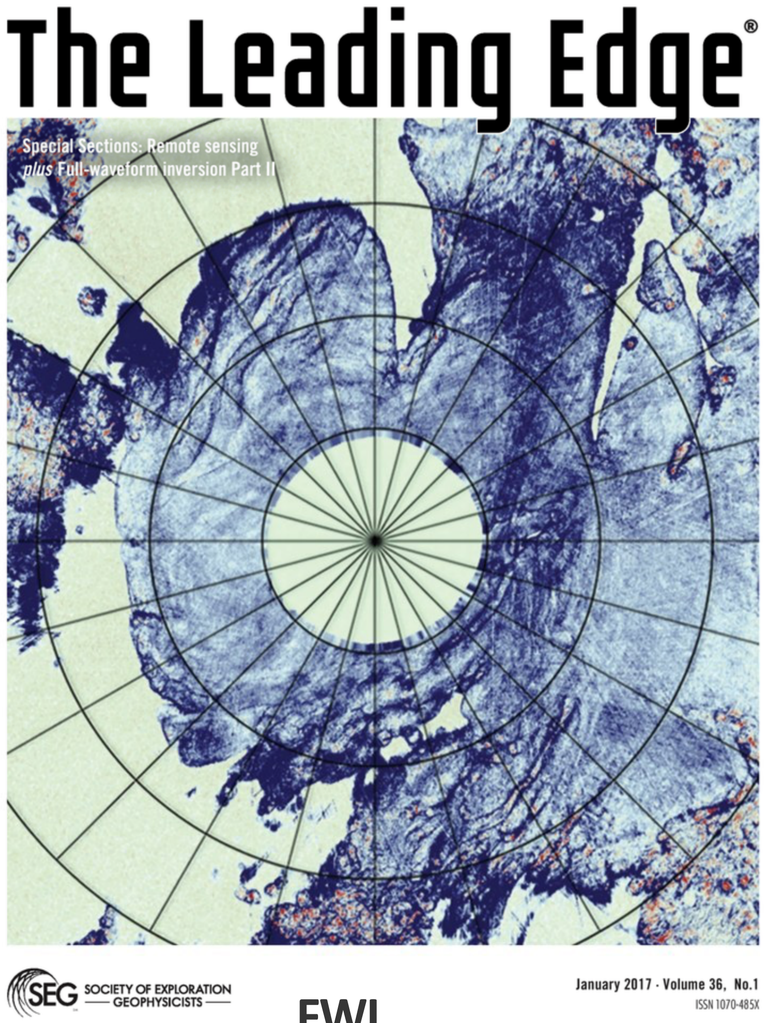
- algorithm development for digital image processing
- interactive seismic interpretation
- and is the recipient of
  - 2008 ECE Outstanding Junior Faculty Member Award
  - 2017 Steven A. Denning Global Engagement Award
  - best Paper Award, IEEE ICIP 2019 (out of 960 papers)

Recognition

Dr. Felix J. Herrmann is recognized as a world-leader in

- algorithm development for wave-based inversion
- (time-lapse) seismic data acquisition & wavefield reconstruction
- is the recipient of
  - 2019 SEG Distinguished lecturer “Sometimes it pays to be cheap – Compressive time-lapse seismic data acquisition”
  - 2020 Fessenden award

imaging
w/
multiples



FWI
w/
constraints

acquisition
w/
Compressive Sensing

ML4Seismic partnership

ML4Seismic

Aims to

- drive innovations in artificial-intelligence assisted seismic imaging, interpretation, analysis & monitoring in the cloud
- low-environmental impact time-lapse acquisition & monitoring
- data-constrained image segmentation & classification
- data-driven & physics-constrained machine learning & uncertainty quantification
- **2 programs in one**

Philanthropic research directed gift program carries *no* overhead (opposed to 64.6 % overhead for sponsored research* at Gatech)

*https://osp.gatech.edu/rates

Benefits

Charter Partner at $180k or more (Annual):

- possibilities for recruitment, internships, engagement w/ students & faculty
- up to 5 complementary registrations Fall & Spring meetings
- opportunities to engage w/ students and faculty on research projects
- access to reproduce our results via creative commons & open source licenses
- 2 complementary registrations professional training
- $1\times$ a year information session to discuss new research directions
- invitation of unto 5 company reps to attend ML4Seismic hackatons
- access to Beta testing ML4Seismic's open source software
- recognition as Diamond sponsor

Benefits

Executive Partner at $90-179k (Annual):

- possibilities for recruitment, internships, engagement w/ students & faculty
- up to **3** complementary registrations Fall & Spring meetings
- opportunities to engage w/ students and faculty on research projects
- access to reproduce our results via creative commons & open source licenses
- **1** complementary registrations professional training
- ~~1 × a year information session to discuss new research directions~~
- ~~invitation of unto 5 company reps to attend ML4Seismic hackatons~~
- ~~access to Beta testing ML4Sesimic's open source software~~
- recognition as Platinum sponsor

Two-tier program

Vetted by Georgia Tech to protect its Tax exempt status

- *“Under no conditions will any particular RESEARCH RESULTS be linked, or given the perception of being linked to a specific donation by any individual PARTICIPANT. ” **
- no explicit deliverables

Most importantly you have direct access to our teams!

Option to give input to the research program…

*** from OPERATING GUIDELINES Center for Machine Learning for Seismic Industry Partners Program (ML4Seismic)**

Gifts

from ML4Seismic partners

Your gifts are for 100% used to

- support our students (stipend, tuition, etc.)
- fund our post doctoral fellows
- pay for travel
- gain access to Cloud compute
- budget permitting free-up director's time (summer salary & teaching release)

Open source model
advantages

New model:

- driving rapid innovations as in Machine Learning & AI
- Chevron, Total, & Equinor are releasing some of their codes as open source
- undergirds more & more public-private partnerships
- initiatives towards open-source endowed professorships

Northern Lights CCS Program (Equinor, Microsoft, Shell, Total):

- all codes released as open source
- part of the Open Group OSDU

ML4Seismic

Research findings are made available through

- publications in peer reviewed journals
- during presentations at conferences
- during presentations at ML4Seismic events (Creative Commons License)
- made reproducible open source software on GitHub and Zenodo (MIT License)

No formal IP

- agreement much simpler
- geared to rapidly drive innovations
- widely used model by US universities

Non-negotiable OPERATING GUIDELINES are available on request.

Repositories – slimgroup

open MIT licensed code on GitHub

General purpose open-source software (OSS) packages

- JUDI.jl – the Julia Devito Inversion framework
- SetIntersectionProjection.jl – projections onto intersections & sums of sets
- InvertibleNetworks.jl – building blocks for invertible neural networks
- JOLI.jl – serial and distributed linear operators in Julia

Specialized examples

- FastApproximateInference.jl – variational inference for inverse problems
- XConv – Julia/Python code for memory efficient CNNs
- TimeProbeSeismic.jl – low memory WE based inversion

Repositories – OLIVES
on GitHub

Open-source software (OSS) packages

- ISI – Salt Dome Interpretation Tool
- S3I – seismic imaging, survey, and imaging
- dippykit – a Python Library for Digital Image Processing

Open source benchmark datasets

- LANDMASS – North-Sea Dataset of Migrated Aggregated Seismic Structures
- F3Facies – A Machine Learning Benchmark for Facies Classification
- CoMMonS – Challenging Microscopic Material Surface Dataset

Value proposition

Energy transition is having a major impact on Oil & Gas industry

- reduced research & development capacity
- increased demand for technology (e.g. CCS)

Public-private partnerships w/ universities

- lowers costs & increase rate of innovation
- access to next-generation of talent
- success hinges on access to training datasets & compute

Will allow us to tackle important problems & to become part of the solution…

This meeting

Formal plenary sessions

talks recorded / Q&A not recorded

Monday:

- **Deployment of Active Machine Learning**
  (Chair: Ali Siahkoohi)
- **Seismic Imaging and Processing in the Cloud**
  (Chair: Ahmad Mustafa)

Tuesday:

- **Explainability Paradigms in AI**
  (Chair: Mohit Prabhushankar)
- **Seismic Acquisition, Inversion, and Monitoring**
  (Chair: Rafael Orozco)

Informal parallel sessions

not recorded

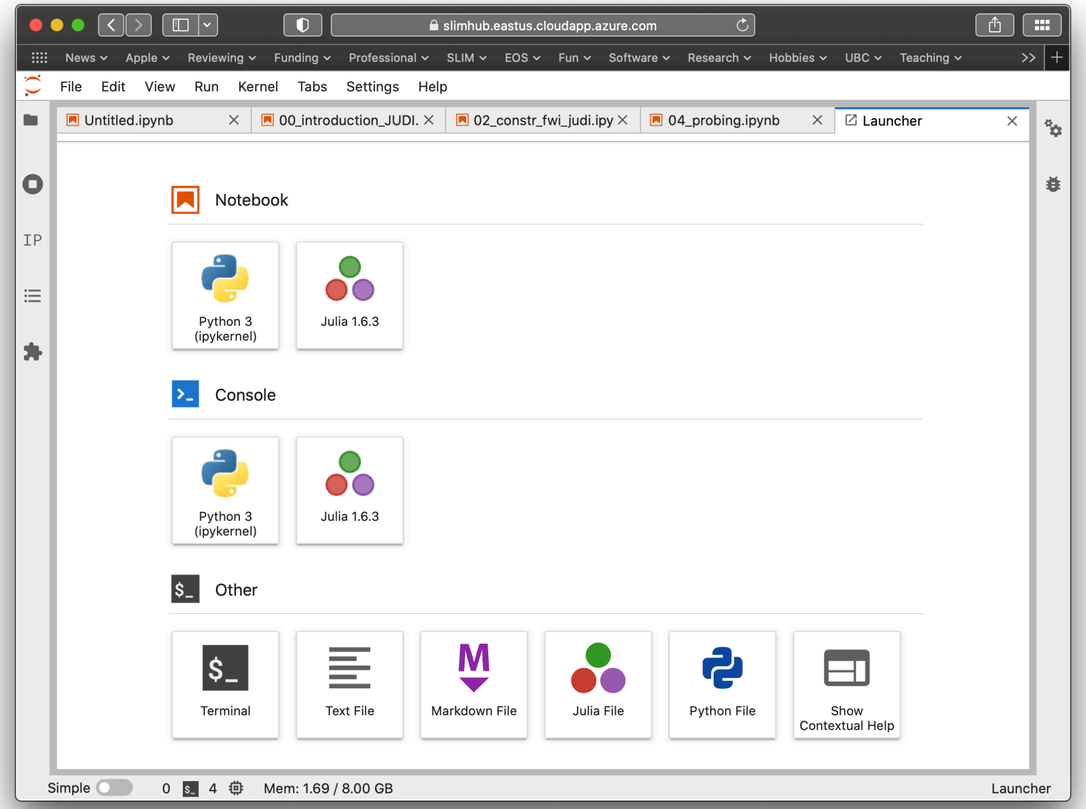
Mon/Tuesday:

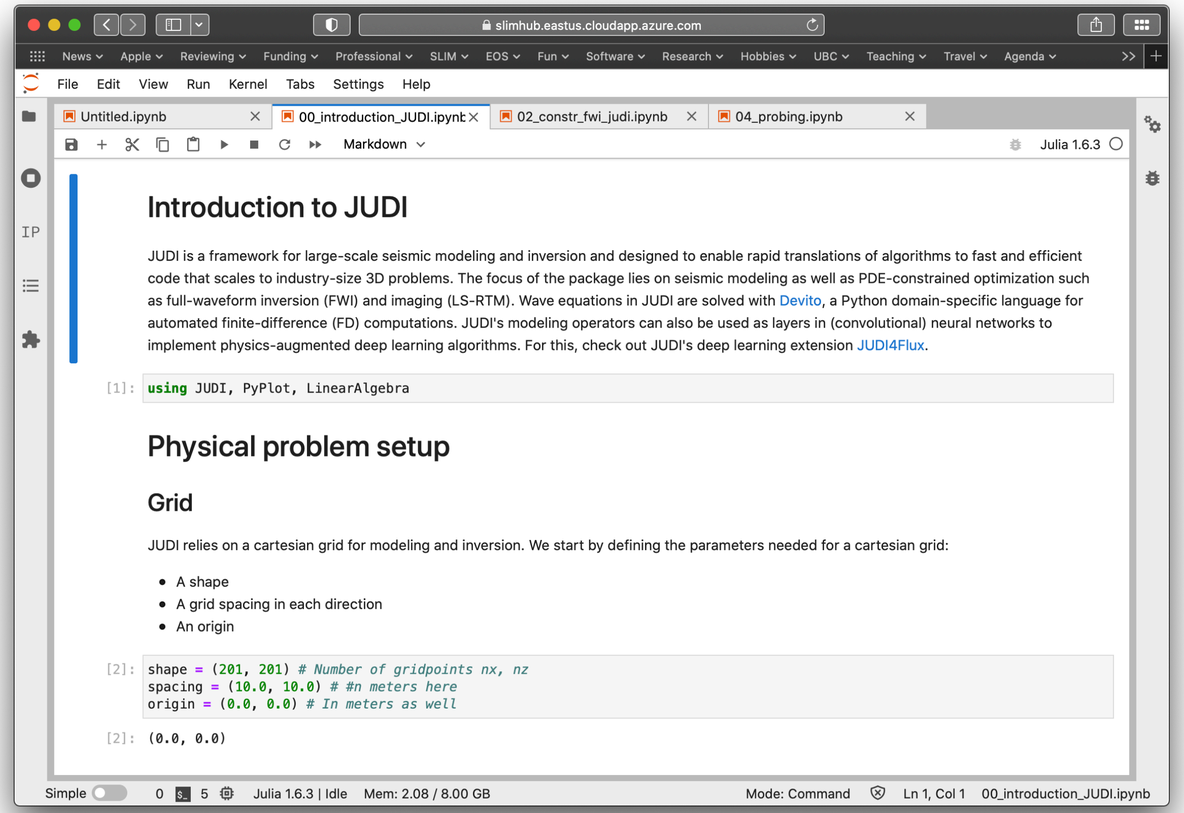
- **Breakout 1. Active Machine Learning, Explainability, and Uncertainty**
  (**Chair:** Ghassan AlRegib)
- **Breakout 2. Scalable Software in the Cloud**
  (**Chair:** Mathias Louboutin)
- **Breakout 3. Seismic Imaging & CCS Monitoring w/ Uncertainty Quantification**
  (**Chair:** Felix J. Herrmann)

Please stay in Teams meeting so you can be assigned to breakout room!

Hands-on tutorials

https://ml4shub.eastus.cloudapp.azure.com/





Program – Monday 22 November

Plenary sessions
Monday

09:00—09:25 AM	Felix J. Herrmann	Introduction to the Meeting
		Deployment of Active Machine Learning (Chair: Ali Siahkoohi)
09:25—09:50 AM	Ahmad Mustafa	Human in the Loop: Seismic Interpretation through Active Learning
09:50—10:15 AM	Ryan Benkert	The Value of Learning Dynamics in Seismic Interpretation
10:15—10:30 AM		*Coffee Break*
		Seismic Imaging and Processing in the Cloud (Chair: Ahmad Mustafa)
10:30—10:55 AM	Philipp Witte	Redwood - Towards clusterless supercomputing in the cloud
10:55—11:20 AM	Mathias Louboutin	ML4Seismic Open Source Software environment
		Machine Learning with Uncertainty (Chair: Mathias Louboutin)
11:20—11:45 AM	Ali Siahkoohi	Uncertainty quantification in imaging and automatic horizon tracking – a Bayesian deep-prior based approach
11:45—12:10 PM	Ali Siahkoohi	Multifidelity conditional normalizing flows for physics-guided Bayesian inference
12:10—12:35 PM	Ryan Benkert	Underspecification in Seismic Interpretation
12:35—12:45 PM		Discussion
02:00—05:00 PM		Informal sessions

Breakout sessions
Monday

02:00—05:00 PM		Informal sessions
	Ghassan AlRegib	Breakout 1. Active Machine Learning and Explainability, and Uncertainty
02:00—03:00 PM		Human-in-the-Loop Systems
03:00—04:00 PM		Explainability and Uncertainty
04:00—05:00 PM		Trust in Seismic Interpretation Models
	Mathias Louboutin	Breakout 2. Scalable Software in the Cloud
02:00—02:30 PM	Mathias Louboutin	Walkthrough Julia installation
02:30—03:15 PM	Mathias Louboutin	Basics wave-based inversion (SegyIO, JUDI, constraints)
03:15—04:00 PM	Mathias Louboutin	Automatic differentiation (ChainRules, JOLI, JUDI)
04:00—05:00 PM	Mathias Louboutin	Serveless HPC in the Cloud (Devito and JUDI4Cloud)
	Felix J. Herrmann	Breakout 3. Seismic Imaging & CCS Monitoring w/ Uncertainty Quantification
02:00—02:30 PM	Ali Siahkoohi	Background sampling from the posterior distributions via MCMC
02:30—03:15 PM	Ali Siahkoohi	Background (conditional) normalizing flows
03:15—04:00 PM	Rafael Orozco	Training of normalizing flows
04:00—04:30 PM	Felix J. Herrmann	Future research directions

Program – Tuesday 23 November

Plenary sessions

Tuesday

08:50—09:00 AM		*Sign in on virtual event*
		Explainability Paradigms in AI (Chair: Mohit Prabhushankar)
09:00—09:25 AM	Rafael Orozco	Variational inference for artifact removal of adjoint solutions in photoacoustic inverse problems
09:25—09:50 AM	Mohit Prabhushankar	Contrastive explanations and robustness for recognition in data
09:50—10:15 AM	Ahmad Mustafa	Making Black-boxes Transparent through Explainable and Interpretable Machine Learning
10:15—10:30 AM		*Coffee Break*
		Seismic Acquisition, Inversion, and Monitoring (Chair: Rafael Orozco)
10:30—10:55 AM	Yijun Zhang	Improved seismic survey design by maximizing the spectral gap with global optimization
10:55—11:20 AM	Gabrio Rizzuti	A dual formulation of wavefield reconstruction inversion for large-scale seismic inversion
11:20—11:45 AM	Ziyi (Francis) Yin	Improved seismic monitoring of CO_2 sequestration with the weighted joint recovery model
		Machine Learning at Scale (Chair: Ziyi (Francis) Yin)
11:45—12:10 PM	Mathias Louboutin	Randomized linear algebra for inversion
12:10—12:35 PM	Thomas Grady	Distributed Fourier Neural Operators
12:35—12:45 PM		Discussion

Breakout sessions

Tuesday

	Ghassan AlRegib	Breakout 1. Active Machine Learning and Explainability, and Uncertainty
02:00—03:00 PM		Human-in-the-Loop Systems
03:00—04:00 PM		Explainability and Uncertainty
04:00—05:00 PM		Trust in Seismic Interpretation Models
	Mathias Louboutin	Breakout 2. Scalable Software in the Cloud
02:00—02:30 PM	Mathias Louboutin	Walkthrough Julia installation
02:30—03:00 PM	Rafael Orozco	InvertibleNetworks.jl
03:00—03:45 PM	Ziyi (Francis) Yin	Seis4CSS open source framework
03:45—04:15 PM	Yijun Zhang	Acquisition design and wavefield reconstruction (code)
04:15—04:45 PM	Mathias Louboutin	Randomized trace estimation
	Felix J. Herrmann	Breakout 3. Seismic Imaging & CCS Monitoring w/ Uncertainty Quantification
02:00—02:45 PM	Felix J. Herrmann	Simulation-based seismic monitoring design
02:45—03:45 PM	Yijun Zhang	Background acquisition design & wavefield reconstruction (methods)
03:45—04:15 PM	Ziyi (Francis) Yin	Background Fourier Neural Operators
04:15—04:30 PM	Felix J. Herrmann	Future research directions

Your input

To facilitate interaction

- Q&A after each 20 min talk
- extra 10 min Q&A after each morning session
- extensive Q&A & discussions during afternoon sessions

Questions can be asked at end formal talks & during+after parallel breakout sessions.

To ask a question

- post in chat and/or “raise hand”
- you will be unmuted
- Q&A and informal sessions will not be recorded

Outcomes

ML4Seismic meeting

At the end of the meeting

- good idea what we are up to
- who we are & what our students are capable of
- what value we create for your organization
- what is next
- ways to improve
- accelerate innovation & training of talent

Enjoy the meeting!