47ème journée ISS France

Jeudi 8 février 2024

PROGRAMME

Lieu: MINES Paris, Amphi L109
60 Bd Saint Michel, 75272 PARIS

13:20 – 13:30 Introduction de la journée (Accueil à partir de 13h15)

Session 1 (13:30 – 15:00)

13:30 – 14:00 **Packed-Ensembles for Efficient Uncertainty Estimation**

Olivier Laurent[1, 2], Adrien Lafage[2], Enzo Tartaglione[3], Geoffrey Daniel[1], Jean-Marc Martinez[1], Andrei Bursuc[4] et Gianni Franchi[2]
Université Paris-Saclay, CEA, SGLS,[1] U2IS, ENSTA Paris, Institut Polytechnique de Paris,[2] LTCI, Télécom Paris, Institut Polytechnique de Paris,[3] Valeo.ai[4]

14:00 – 14:30 **CLIP-QDA: An Explainable Concept Bottleneck Model**

Kazmierczak Rémi[1], Berthier Eloïse[1], Frehse Goran[1], Franchi Gianni[1]
U2IS, ENSTA Paris, Institut Polytechnique de Paris[1]

14:30 – 15:00 **A posteriori Deep Learning segmentation quality estimation based on Prediction Entropy**

José-Marcio Martins da Cruz[1], Mateus Sangalli[1], Etienne Decencière[1], Santiago Velasco-Forero[1], Thérèse Baldeweck[2]
MINES Paris, PSL Research University, Centre for Mathematical Morphology[1], L'Oréal Research and Innovation[2]

15:00 – 15:15 *Pause*

Session 2 (15:15 – 16:15)

15:15 – 15:45 **Combining Machine-Learning and Physics-based Models to Mitigate Stick-Slip in Real-Time**

Hana Yahia[1,2], Thomas Romary[1], Laurent Gerbaud[1], Bruno Figliuzzi[1], Florent Di Meglio[1], Stéphane Menand[2], Mohamed Mahjoub[2]
MINES Paris – Université PSL[1], Helmerich & Payne[2]

15:45 – 16:15 **Self-Supervised Physics-Informed Surrogate Model for Elastic Local Fields in Polycrystals**

Lucas Monteiro Fernandes[1] , Samy Blusseau[1] , Philipp Rieder[2] , Henry Proudhon[3] , Matthias Neumann[2] , Volker Schmidt[2] , François Willot[1]
Center for Mathematical Morphology, MINES Paris - PSL University[1,] Institute of Stochastics, Ulm University, Germany[2,] Center for Materials Science, Mines Paris - PSL University[3]

Session 3 (16:30 – 17:30)

16:30 – 17:00 **Continuous simulation of heterogeneous media: The Karhunen-Loève approach versus the turning bands method**

Christian Lantuéjoul
Equipe Géostatistiques, Centre de géosciences, MINES Paris - Université PSL

17:00 – 17:30 **The quest for a random set that maximizes minimal paths**

François Willot[1] and Martin Idiart[2]
Centre for Mathematical Morphology, MINES Paris, Université PSL[1], Universidad Nacional de La Plata[2], Argentina

Packed-Ensembles for Efficient Uncertainty Estimation

Olivier Laurent[1, 2], Adrien Lafage[2], Enzo Tartaglione[3], Geoffrey Daniel[1], Jean-Marc Martinez[1], Andrei Bursuc[4] et Gianni Franchi[2]
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Deep Ensembles (DE) are a prominent approach for achieving excellent performance on key metrics such as accuracy, calibration, uncertainty estimation, and out-of-distribution detection. However, hardware limitations of real-world systems constrain to smaller ensembles and lower-capacity networks, significantly deteriorating their performance and properties. We introduce Packed-Ensembles (PE), a strategy to design and train lightweight structured ensembles by carefully modulating the dimension of their encoding space. We leverage grouped convolutions to parallelize the ensemble into a single shared backbone and forward pass to improve training and inference speeds. PE is designed to operate within the memory limits of a standard neural network. Our extensive research indicates that PE accurately preserves the properties of DE, such as diversity, and performs equally well in terms of accuracy, calibration, out-of-distribution detection, and robustness to distribution shift.

CLIP-QDA: An Explainable Concept Bottleneck Model

Kazmierczak Rémi[1], Berthier Eloïse[1], Frehse Goran[1], Franchi Gianni[1]
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In this presentation, we introduce an explainable algorithm designed from a multi-modal foundation model, that performs fast and explainable image classification. Drawing inspiration from CLIP-based Concept Bottleneck Models (CBMs), our method creates a latent space where each neuron is linked to a specific word. Observing that this latent space can be modeled with simple distributions, we use a Mixture of Gaussians (MoG) formalism to enhance the interpretability of this latent space. Then, we introduce CLIP-QDA, a classifier that only uses statistical values to infer labels from the concepts. In addition, this formalism allows for both local and global explanations. These explanations come from the inner design of our architecture, our work is part of a new family of greybox models, combining performances of opaque foundation models and the interpretability of transparent models. Our empirical findings show that in instances where the MoG assumption holds, CLIP-QDA achieves similar accuracy with state-of-the-art methods CBMs. Our explanations compete with existing XAI methods while being faster to compute.

A posteriori Deep Learning segmentation quality estimation based on Prediction Entropy

José-Marcio Martins da Cruz[1], Mateus Sangalli[1], Etienne Decencière[1], Santiago Velasco-Forero[1], Thérèse Baldeweck[2]

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Image segmentation is a common intermediate operation in many image processing applications. On automated systems it is important to evaluate how well it, or its subsystems are performing without access to the Ground Truth. In Deep Learning based image segmentation there are very few methods to evaluate the output quality without using a ground truth. Most of them are based on the uncertainty (variance or standard deviation) of the prediction and can be applied to Bayesian Neural Networks, but not to Convolutional Neural Networks. In this research we propose to use the Entropy as a measure of uncertainty applied to the segmented image predicted by the Neural Network and some indicators based on it.

The method is tested in a segmentation task of labeled skin images. The entropy based indicators are evaluated without knowing the ground truth and compared with indicators based on the real labels (Jaccard, Dice and Average Symmetrical Surface Distance). This experimentation showed that they are correlated and some Entropy based indicators can predict quite well the ground truth based indicators.

Combining Machine-Learning and Physics-based Models to Mitigate Stick-Slip in Real-Time

Hana Yahia[1,2], Thomas Romary[1], Laurent Gerbaud[1], Bruno Figliuzzi[1], Florent Di Meglio[1], Stéphane Menand[2], Mohamed Mahjoub[2]

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Objectives/Scope:

Downhole vibrations can be the source of significant drilling problems in unconventional wells, such as frequent tool failures leading to higher drilling costs. Detecting them while drilling is essential to improve drilling practice. Torsional stick-slip is one of the most destructive types of downhole vibrations, where the bit rotation speed fluctuates between zero and several times the surface rotation speed. For real-time detection, surface data is generally used to diagnose this drilling dysfunction. In recent years, detection algorithms relying on artificial intelligence have been proposed. An important drawback of the AI method is that the trained models could be limited in application to wells in the same field, with similar geological rock formations and similar BHAs. We aim to address this limitation and investigate solutions that enable the generalization of these approaches in adding physics-based features.

Methods, Procedures, Process:

First, a baseline data driven model was trained on field measurements from different wells to predict stick-slip vibrations using surface data. Then, to improve the generalizability, two solutions were proposed: (i) a transfer learning technique was tested to adapt the original model to a new subject well. Data from the only the beginning of the drilling time is used to make the model adjust itself to the new well; (ii) a hybrid machine learning and physics-based prediction model was trained using additional engineered features like contact forces and drillstring's natural frequencies. These additional features give the model more information about the drillstring rigidity and wellbore condition.

Results, Observations, Conclusions:

The baseline data driven model's capability to recognize surface data patterns corresponding to severe downhole stick-slip vibration is demonstrated when training and testing on each well separately. As expected, when the model is tested on another well from a different field, the differentiation of the sequences' stick-slip severity levels is less successful. The employed transfer learning

technique has drastically improved the generalizability of the model, but it requires that the new drilling data is sufficiently heterogeneous. This means that the new well has already encountered different stick-slip severity levels, which is not always the case. The hybrid machine learning physics model was tested too. It takes less time to be trained, which means it's easier to distinguish the sequence's stick-slip severity than the data driven model.

Novel/Additive Information:

This work aims to couple between data driven and physical models for a better prediction of stick-slip and drilling dysfunctions in general and to make it used for wells with different BHAs and geological rock formations.

Self-Supervised Physics-Informed Surrogate Model for Elastic Local Fields in Polycrystals

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Keywords: *Physics-informed, self-supervised, surrogate model, polycrystalline materials, representative elementary volume, periodic boundary conditions, linear elasticity.*

We propose a self-supervised physics-informed neural network for explicitly solving anisotropic linear elasticity on periodic heterogeneous media, with an application to polycrystalline materials. Our method relies on linking a convolutional neural network with residual connections to non-learnable layers that take inspiration from the mechanical problem addressed by Fast Fourier Transform (FFT) algorithms. Spatial differential operators are discretized via finite differences consistently with the Green operator used in the FFT computations and are treated as convolutions with fixed kernels. One of the layers informs the network of the known relation between crystalline orientation and stiffness tensor. A physical loss function derived from the stress field allows for updating weights and biases with no need of a loss term accounting for supervision on the ground truth given by an FFT solver. The network is trained on untextured synthetic microstructures realized via a stochastic generator based on point processes and tessellations. Once trained, the machine learning pipeline is able to predict the periodic part of displacement field from the unit quaternion field of an artificial representative elementary volume (REV), without iterating. The predictions are validated by comparison with the FFT solution. Furthermore, possible applications and extensions of the method are discussed, including arbitrary elasticity tensors and loading directions, and comparisons between machine learning predictions and numerical or analytical estimates in terms of effective properties.

The quest for a random set that maximizes minimal paths

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We derive closed-form expressions for the effective conductivity of a class of powerlaw «differential» laminates in arbitrary dimension, studied in previous works [1]. Emphasis is put on the weakly and strongly nonlinear regimes, and on the asymptotic behavior of such composite in the «dilute limit» of a vanishingly small volume fraction of one of the two phases. In the strongly nonlinear limit, we examine the behavior of these solutions as the partial derivative equations loose ellipticity. The domain of validity of the resulting expressions are examined, and we provide a geometric interpretation of the results, relevant to field localization. The behavior of the solutions at increasing dimensions, and whether they could represent bounds is examined.

[1] Idiart, M. I., & Castañeda, P. P. (2013). Estimates for two-phase nonlinear conductors via iterated homogenization. /Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences/, /469/(2153), 20120626.