IUTAM SYMPOSIUM
Data-Driven Mechanics and Surrogate Modeling
&
Professor Charbel Farhat
Honoris Causa Doctorate Ceremony
Arts et Métiers Institute of Technology


PROGRAM
October 25-28, 2022
Arts et Métiers Institute of Technology

WELCOME

In their early days, scientific and engineering developments were dominated by empirical understanding which encapsulated the first paradigm of scientific discovery. After the Renaissance, the scientific revolution and the development of calculus led to a new scientific viewpoint whereby physical principles, laws of nature, and engineering models were established by proposing new theoretical constructs that could be verified through specific experiments. This was the second paradigm of scientific discovery. More recently, the computational era, or the third paradigm of discovery, has enabled the solution of complex scientific and engineering problems that were beyond analytically tractable methodologies, using high-fidelity and often high-dimensional computational models.

Today, there is a new, fourth paradigm of discovery, which is a data-driven science and engineering framework whereby physical laws and models are directly inferred from data. Therefore, there is an increasing change in the objective of computational algorithms used in simulations. Until now, the focus has centered on accurately discretizing systems of linear and nonlinear continuum equations derived from physical laws and principles, and/or inferred from observations grounded in limited experimental data. Today, the availability of data, whether experimental or numerical, and the complexity of equations are no longer a major limitation, to the point that physical processes can be computed without resorting to analytical laws or necessarily high-dimensional computational models. External as well as low-dimensional internal representations of systems are now possible and capable of predicting the correct outputs for given inputs.

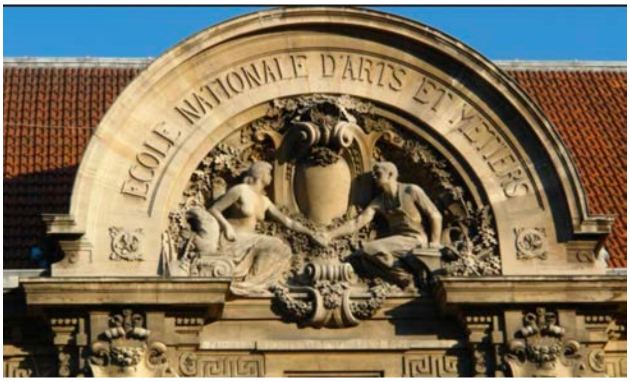
For this endeavor however, new computational algorithms capable of learning the complex behavior of a physical system or its high-dimensional numerical model and establishing its governing behavior directly from data are needed. Examples include the prediction of the nonlinear behavior of solids and fluids under general conditions directly from experimenal data, without specifying a conventional form of constitutive relations; and the construction of parametric, real-time surrogate models, from numerical data sampled using high-dimensional computational models.

Hence, the purpose of this workshop is to bring about novel, state-of-the-art contributions to data-driven mechanics and surrogate modeling.

TOPICS

- Data science: data sampling, data representation, data fusion, data visualization, data classification, data clustering, data compression, data vs. information, …
- Manifold learning and nonlinear dimensionality reduction
- Model order reduction, surrogate modeling, and meta-modeling
- Advanced machine learning techniques, including deep learning and active learning
- Mechanics-informed, physics-informed, and other forms of constrained learning
- Digital twins of the instance and aggregate types
- Engineering and scientific applications:
    - data-driven engineered materials & meta-materials
    - data-driven constitutive modeling and internal variables discovering and modeling
    - data-driven multi-scale modeling
    - parametric, nonlinear, projection-based model order reduction
    - data-driven model enrichment/updating

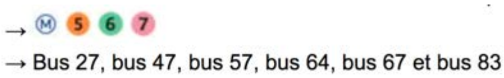
LOCATION



ENSAM (Ecole Nationale Supérieure d'Arts et Métiers)
Amphitheatre BEZIER (Conference Room)
155 Boulevard de l'Hôpital
75013 Paris

AN IDENTITY CARD / PASSEPORT IS REQUIRED FOR ACCESS

Closest metro stations: Place d'Italie (lines 5, 6 & 7)



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Nicolas HASCOET
Daniele DI LORENZO
Angelo PASQUALE

ORGANIZERS

16:00	**Welcome**
17:00 - 19:00	 **Honoris Cause Doctorate @ Arts et Métiers** **Professor Charbel FARHAT** **Stanford University** Charbel Farhat is the Vivian Church Hoff Professor of Aircraft Structures in the School of Engineering and the James and Anna Marie Spilker Chair of the Department of Aeronautics and Astronautics, at Stanford University. He is also Professor of Mechanical Engineering, Professor in the Institute for Computational and Mathematical Engineering, and Director of the Stanford-King Abdulaziz City for Science and Technology Center of Excellence for Aeronautics and Astronautics. He currently serves on the Space Technology Industry-Government-University Roundtable. From 2007 to 2018, he served as the Director of the Army High Performance Computing Research Center at Stanford University; and from 2015 to 2019, on the United States Air Force Scientific Advisory Board (SAB). He was designated by the US Navy recruiters as a Primary Key-Influencer and flew with the Blue Angels during Fleet Week 2014. He holds a Ph.D. in Civil Engineering from the University of California at Berkeley. He is a Member of the National Academy of Engineering (US), a Member of the Royal Academy of Engineering (UK), a Member of the Lebanese Academy of Sciences, a Docteur Honoris Causa of Ecole Normale Superieure Paris-Saclay, a Docteur Honoris Causa of Ecole Centrale de Nantes, a designated ISI Highly Cited Author in Engineering, and a Fellow of six professional societies: the Society of Industrial and Applied Mathematics (SIAM); the American Society of Mechanical Engineers (ASME); the International Association of Computational Mechanics (IACM); the World Innovation Foundation (WIF); the United States Association of Computational Mechanics (USACM); and the American Institute of Aeronautics and Astronautics (AIAA). He was knighted in the Order of Academic Palms and awarded the Medal of Chevalier dans l'Ordre des Palmes Academiques. He is the recipient of several other professional and academic distinctions including the Lifetime Achievement Award from the ASME's Computers & Information in Engineering Division; the Spirit of St Louis Medal from the ASME's Aerospace Division; the AIAA Ashley Award for Aeroelasticity and the Structures, Structural Dynamics and Materials Award from the AIAA; the John von Neumann Medal, the Computational and Applied Sciences Award, and the R. H. Gallagher Special Achievement Award from the USACM; the Grand Prize from the Japan Society for Computational Engineering and Science (JSCES); the Gauss-Newton Medal, the IACM Award, the Computational Mechanics Award, and the Computational Mechanics Award for Young Investigators from the IACM; the Gordon Bell Prize and the Sidney Fernbach Award from the Institute of Electrical and Electronics Engineers (IEEE) Computer Society; the Engineer of the Year Award from the AIAA Rocky Mountain Section; the Modeling and Simulation Award from the Department of Defense; the IBM Sup'Prize Achievement Award; the Arch T. Colwell Merit Award from the Society of Automotive Engineers (SAE); the CRAY Research Award; and the United States Presidential Young Investigator Award from the National Science Foundation and the White House. Professor Farhat is also Editor-in-Chief of the International Journal for Numerical Methods in Engineering and Editor of the International Journal for Numerical Methods in Fluids. He has been a plenary or keynote speaker at numerous national and international scientific meetings.
19:00	**Cocktail**

OCTOBER 26th : MORNING

08:15 - 08:30	**Opening Ceremony**
08:30 - 09:15	**Plenary Lecture #1** **Eleni CHATZI, ETH, Switzerland** **Robust Dynamical Systems Monitoring: Learning by Modeling**
09:15 - 09:45	Data-driven harmonic analysis for multi-scale construction of arbitrary anisotropic damage models with minimal number of internal variables. J. Yvonnet, Qi-Chang HE, Pengfei LI
09:45 - 10:15	Convolutional neural network for computational homogenization of heterogeneous materials. F. Aldakheel, P. Wriggers
10:15 - 10:45	Data-oriented constitutive modeling. R. Shoghi, J. Schmidt, A. Hartmaier
10:45 - 11:15	**Coffee Break**
11:15 - 11:45	Combination of an adaptive FFT-based model order reduction technique and a clustered description of the microstructure J. Waimann, C. Gierden, A. Schmidt, B. Svendsen, S. Reese
11:45 - 12:15	Data-Driven methods for computational homogenization: Microstructure reconstruction and accelerated multiscale schemes. K.A. Kalina, P. Seibert, L. Linden, A. Raßloff, M. Kästner
12:15 - 12:45	Generative models approach on TFM data based on variational inference for multi-fidelity data generation. G.E. Granados, G. Colombera, F. Gatti, S. Robert, R. Miorelli, D. Clouteau.
12:45 - 14:00	**Lunch**

OCTOBER 26th : AFTERNOON

14:00 – 14:30	A nonparametric probabilistic method for physics-based data-driven modeling, uncertainty quantification, and digital twinning. C. Farhat, M.J. Azzi, C. Ghnatios
14:30 - 15:00	Physics knowledge as an inductive bias in scientific machine learning. Q. Hernandez, B. Moya, A. Badias, F. Chinesta, E. Cueto.
15:00 - 15:30	Hybrid twins based on optimal transport. S. Torregrosa, V. Champaney, A. Ammar, V. Herbert, F. Chinesta
15:30 - 16:00	**Coffee Break**
16:00 - 16:30	Explainability of data-driven turbulence models based on sparse Bayesian learning. S. Cherroud, X. Merle, P. Cinnella, X. Gloerfelt
16:30 - 17:00	Deep reinforcement learning for fluid mechanics. E. Hachem, P. Meliga, H. Ghraieb, R. Nemer, A. Goetz, R. Valette, P.J. Rico, J. Viquerat, A. Larcher
17:00 - 19:00	**Express Presentations** (3-minute videos pertaining to poster presentations)
19:00 - 21:00	**Poster and Wine and Cheese Session**

OCTOBER 27th : MORNING

08:30 - 09:15	**Plenary Lecture #2** **Yannis KEVREKIDIS, Johns Hopkins University, USA** **No equations, no variables, no parameters, no space, no time.** **Data and the modeling of complex systems**
09:15 - 09:45	Discrete and continuous symmetry reduction for chaotic flow in two dimensions. S. Kneer, G. Rigas, N.B. Budanur
09:45 - 10:15	PGD framework for non-linear beam dynamics. S. Rishmawi, F.P. Gosselin
10:15 - 10:45	Accelerating inverse analyses with non-local model order reduction via projection-tree reduced order modeling. S.N. Rodriguez, N.A. Apetre, A.P. Iliopoulos, J.C. Steuben, A.J. Birnbaum, J.G. Michopoulos
10:45 - 11:15	**Coffee Break**
11: 15 - 11:45	Quasi real time optimization of turbulent mixed convection flows by using a POD surrogate genetic algorithm. M. Oulghelou, C. Béghein, C. Allery, A. Hamdouni, D. Razafindralandy
11: 45 - 12:15	Locally-reduced FETI for the efficient solution of transient problems with local nonlinearities. B. Nijhuis, J. Havinga, H.J.M. Geijselaers, A.H. van den Boogaard
12:15 - 12:45	Piecewise-quadratic approximation manifold for delaying the Kolmogorov barrier in nonlinear projection-based model order reduction. J. Barnett, C. Farhat
12:45 - 14:00	**Lunch**

OCTOBER 27th : AFTERNOON

14:00 - 14:30	Multi-fidelity physics-constrained neural network with minimax. D. Liu, Y. Wang
14:30 - 15:00	Unifying framework for data-driven linear modeling. J.C. Loiseau, S.L. Brunton
15:00 - 15:30	Integrating catalog data with topology optimization using neural networks. S. Sridhara, A. Chandrasekhar, K. Suresh
15:30 – 16:00	Overcoming non-locality in model order reduction of smoothed particle hydrodynamics with graph neural networks. L.K. Magargal, S.N. Rodriguez, J.W. Jaworski, A.P. Iliopoulos, J.G. Michopoulos
16:00 - 16:30	**Coffee Break**
16:30 - 17:00	Higher order invariant manifolds parameterization of geometrically nonlinear structures modelled with large finite element models. A. Vizzaccaro, A. Opreni, A. Martin, L. Salles, A. Frangi, C. Touzé
17:00 - 17:30	Thermodynamically admissible reinforcement learning in the development of cognitive digital twins. B. Moya, A. Badías, D. González, F. Chinesta, E. Cueto
17:30 - 18:00	From ontologies and FAIR data to machine learning-based high-throughput data mining in materials science. S. Sandfeld
18:00 – 18:30	Data-driven multiscale methods for the design of short fiber reinforced polymer components: An industrial perspective. F. Welschinger

OCTOBER 28th : MORNING

08:30 - 09:15	**Plenary Lecture #3** **George KARNIADAKIS, Brown University, USA** **The next generation of neural operators**
09:15 - 09:45	Hybrid machine learning approach to exploit process-structure linkages of friction surfacing driven by experimental and numerical data. F.E. Bock, Z. Kallien, N. Huber, B. Klusemann
09:45 - 10:15	Clustering-based hyper-reduced order solver for contact mechanics. S. Le Berre, I. Ramière, D. Ryckelynck
10:15 - 10:45	Active learning data generation to efficiently explore microstructure spaces as fundamental basis for training data-driven models in materials design. L. Morand, D. Helm
10:45 - 11:15	**Coffee Break**
11: 15 - 11: 45	Data-driven material modeling employing the theory of representations for tensor functions. J.N. Fuhg, D. Peters, N. Bouklas
11: 45 - 12: 15	Physics-informed neural networks derived from a mCRE functional for constitutive modelling. A. Benady, L. Chamoin, E. Baranger
12:15 - 12:45	A deep learning approach for phase-field fracture modeling. Manav, R. Molinaro, S. Mishra, L. De Lorenzis
12:45 - 14:00	**Lunch**

OCTOBER 28th : AFTERNOON

14:00 - 14:30	A mechanics-informed data-driven framework for learning the constitutive modeling of nonlinear elastic and viscoelastic materials. F. As'ad, C. Farhat
14:30 - 15:00	A model-free data-driven paradigm for multi-scale mechanics. F.F. Rocha, A. Platzer, A. Leygue, M. Ortiz, L. Stainier
15:00- 15:30	A thermodynamically compatible, data-driven computational approach for history-dependent materials. P. Ladeveze, D. Neron, P.W. Gerbaud
16:30 - 16:00	**Coffee Break**
16h00 - 16h30	Model-free data-driven mechanics. M. Ortiz.
16h30-17h00	Robotic multiaxial testing and multiphysics data driven modeling for Digital Twins relevant to naval sustainment applications. J. Michopoulos
17h00 - 17h30	Convolution hierarchical deep learning neural network (C-HiDeNN)-FEM for process design and performance prediction of material systems. W.K. Liu

POSTERS

LIST OF POSTERS A 3-minutes video of each poster will be presented during the plenary session and then discussed during the poster, wine and cheese session
Data-driven kinematics-consistent model order reduction of fluid-structure interaction problems: application to microcapsules in flow. A.V. Salsac, C. Dupont, F. De Vuyst
Data-driven turbulence modeling of buoyant plumes in a stratified environment. M. Mahajan, N. Kumar, D. Shikha, V.K Chalamalla, S.S. Sinha
Data-driven computations of polyurethan foam based on RVE-generated data sets. T. Korzeniowski, K. Weinberg
Inverse design of 2D auxetic porous metamaterials using deep learning. C. Zhang, J. Xie, Y.F. Zhao, A. Shanian, M. Kibesy
Machine learning methods to predict invariant surface elastic properties in FCC metals. X. Chen, R. Dingreville, T. Richeton, S. Berbenni
Data-driven space-dependent mixtures of RANS models for uncertainty quantification in turbulent flow predictions. C. Roques, M. De Zordo-Banliat, G. Dergham, X. Merle, P. Cinnella
Parsimonious shape-parametrized reduced order model for aerodynamic optimization. K. Naffer-Chevassier, F. De Vuyst, Y. Goardou, Y. Tourbier
Transfer learning from a data-driven melt pool dynamics model for improved defect detection in laser powder bed fusion. S. Larsen, P.A. Hooper
Digital twins of defects for artifact-free tomographic reconstruction and improved life span estimation of layered materials. J.C. Steuben, B.D. Graber, A.P. Iliopoulos, J.G. Michopoulos
A meta-framework for machine learning reconstruction of multi-physics datasets with gaps. J.C. Steuben, S.N. Rodriguez, J.G. Michopoulos
Higher order and non-linear dynamic mode decomposition. A.P. Iliopoulos, S.N. Rodriguez, J.G. Michopoulos
Discovery of mechanics laws by proper orthogonal decomposition reduction of ensembles of experimental force-acceleration data (time series) acquired in continuum flexible structures. I.T. Georgiou
Data-driven process modeling of stretch broken carbon fiber composites. D.S. Cairns, R. Amendola, D. Bajwa, M. Egloff, C. Ridgard, C. Ryan

Experimental study of chip formation during orthogonal cutting in atitanium alloy: Contribution of machine learning to large scale image analysis. A. Pouliquen, L. Gallegos-Mayorga, C. Mareau, Y. Ayed, G. Germain
Data-driven surrogate modeling for design exploration: Prototyping challenges and review. O. Bettinotti, J. Bi, V. Oancea
A deep learning framework for the mechanical analysis of fibre composite adhesive. A. Khan, C. Balzani
Using microstructural data to inform multi-physics modeling of pitting corrosion. P.T. Brewick
Predicting the transient dynamics of multistory buildings under earthquake load via deep adversarial network. G. Colombera, F. Gatti
Learning simulators with thermodynamics and geometry. Q. Hernández, A. Badías, F. Chinesta, E. Cueto
Metal additive manufacturing process-structure-property relational linkages using Gaussian process surrogates. R. Saunders, A. Elwany, J. Michopoulos, D. Lagoudas
Topology optimization for heat and mass transfer systems using adjoint and reinforcement learning methods. W.A. Nour, J. Jabbour, D. Serret, P. Meliga, E. Hachem
Deep learning strategies for predictive modeling of turbulent multiphase flows. A. Patil, J. Viquerat, E. Hachem
Exploiting deep graphical models for multiphase flow problems. G. El Haber, J. Viquerat, A. Larcher, D. Ryckelynck, E. Hachem
Hybrid elastoplasticity with data-driven yielding and model-based hardening. J.N. Fuhg, N. Bouklas
On the best (constructive) approximation of square matrices in Laplacian-like form. J.A. Conejero, A. Falcó, M. Mora Jiménez
Learning the flow around arbitrary obstacles by convolutional autoencoders. C. Bermejo, A. Badías, D. González, F. Chinesta, E. Cueto
Data-driven modeling of the plastic yield behaviour of nanoporous metals under multiaxial loading L. Dyckhoff, N. Huber
Data-driven determination of heterogenous CTE via spatially-resolved, diffraction-based sensing. A. Birnbaum, N. Apetre, B.A. Rawlings, B. Graber, J.C. Steuben, A. Iliopoulos, S. Rodriguez, J. Michopoulos

A data-driven approach using neural network for real-time modeling of spot-welded patches under impact. A. Pulikkathodi, E. Lacazedieu, L. Chamoin, J.P. Berro Ramirez, L. Rota, M. Zarroug.
Forecasting heat diffusion on lattices by means of graph neural networks (GNNs). L. Irastorza-Valera, A. Runacher, E. Cueto, L. Saucedo-Mora, F. Chinesta
Certified ROM for parametrized Allen-Cahn equation a priori vs a-posterior errors estimators. M. Azaiez, T. Chacon, L. Wi, C. Xu
Data-driven modelling of the filament shape evolution in fused filament fabrication process. A. Runacher, A. Pasquale, M. Kazemdeh-Parsi, A. Ammar, T. Joffre, C. Salvan, C. Ghnatios, E. Cueto, F. Chinesta
Smart sampling design methods for classification and regression in high dimensional problems. C. Guilhaumon, M. Lavarde, N. Hascoët, F. Chinesta
Real-time structural health monitoring of aeronautics structures: A damage detection and identification approach based on a multidimensional parametric model using the sparse proper generalized decomposition coupled with optimization. M. Jacot, V. Champaney, A. Pasquale, P. Triguero Navarro, F. Chinesta
Data-driven 1D site response. J. Garcia-Suarez, A. Cornet, S. Wattel, J.F. Molinari
Coupling of regular FEM and data-driven elements. by J. Garcia-Suarez, S. Wattel, J.F. Molinari