MOUSSA ATWI

Applied Mathematics (Scientific Computing)

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EXPERIENCE

Internship:

Koopman Theory

Title: "Approximation of Koopman Operators Using Random Basis Functions"

Keywords: "Koopman operators, EDMD, Deeptime, Neural networks, Gaussians".

Description: "Approximation of Koopman operators using Extended Dynamic Mode Decomposition (EDMD) combined with random gaussians and randomly initialised neural networks on deeptime. "Gaussian" and "Rinn", implemented in python and applied to a high dimensional models to estimate Koopman's eigenfunctions and eigenvalues".

Zuse Institute Berlin || ZIB

01/09/2022 – 01/12/2022 | Berlin, Germany

Master's Theses:

- **Koopman Theory**

  Title: "Approximation of Koopman Operators Using Random Basis Functions"

  Keywords: "Koopman operators, EDMD, Random Gaussians and Neural Networks".

  Description: "We went through the theory of Koopman Operators and nonlinear dynamical systems, including the intrinsic coordinates where the dynamics behaves linearly (Koopman Eigenfunctions), invariant sub-spaces, Koopman embedding, and EDMD combined with Monomials, Random Gaussians, and Trained and Untrained Randomly Initialised Neural Networks".

  Zuse Institute Berlin || ZIB

  Dec 2023 – May 2023 | Berlin, Germany

- **Control Theory**

  Title: "Decay Rates of a Timoshenko System with Kelvin-Voigt Damping"

  Keywords: "C_0-Semigroup, Timoshenko beam, Polynomial and Exponential stability".

  Description: "We proved that the energy of the Timoshenko system with Kelvin - Voigt damping, dissipates exponentially or polynomially and the decay rate depends on properties of material coefficient function".

  Lebanese International University

  Feb 2019 – Aug 2019 | Beirut, Lebanon

Seminars (reports and talks) :

- **Optimal Transport**

  Title: "Entropic Regularization of Discrete and Continuous Optimal Transport"

  Keywords: "Kantorovich Formulation, Regularized Problem, Discrete and Relative Entropies, Sinkhorn's Algorithm, Dual Formulation, KL-Divergence, Gibbs Kernel".

  Description: "We show the Convergence with small and large regularization. Scaling the solution through Gibbs kernel. Sinkhorn algorithm allowing us to compute the (EOT) with quadratic cost. Derive the dual problem where strong duality holds."

- **Nonlinear Optimization**

  Title: "Constrained Optimization and Duality. Applications to ML"

  Keywords: "Lagrangian Realaxation and Duality, Coordinate Descent Method, Formulating the SVM Dual, Norm Constrained Optimization and Barrier Methods".

  Description: "Primal and Dual problems, constraint qualifications for Strong duality. ML Applications : Norm constrained optimization and Formulating of SVM dual where the Coordinate and Gradient Descent methods used for solving the SVM dual".

  Technical University

  February - June 2022 | Berlin, Germany

University Projects and Courses:

- **Nonlinear Optimization**

  Convex optimization, conjugate gradient and trust region methods, constrained nonlinear optimization, tangent and linearized cones, ACQ, LICQ, KKT conditions, critical cone, box constraints, active set and Null-space methods, SQP method, etc.

EDUCATION

- M.Sc. in Scientific Computing (GPA 1.2 $\sim$ 3.8 US)

  Technical University of Berlin || TUB

  April 2021 – May 2023 | Berlin, Germany

- M.Sc. in Applied Mathematics (Rank 1, GPA 4.0 US)

  Lebanese International University || LIU

  Feb 2018 – June 2019 | Beirut, Lebanon

- B.Sc. + First year of Master (M1) in Pure Mathematics

  Lebanese University || LU

  Oct 2012 – Sep 2015 | Beirut, Lebanon

ACHIEVEMENTS

- Received A's in the master's thesis and research internship in Koopman Theory, and in the following courses at TU Berlin: Numerical methods for PDEs, Scientific Computing, Probabilistic and Bayesian Modelling, and the Seminar in Nonlinear Optimization.
- Received A's in all the required courses in the master's at LIU.
- Scholarship from Region Nouvelle-Aquitaine for excellence in Mathematics to pursue the master's at the University of Pau.
- Ranking first in Number Theory, first year of master at LU

SKILLS

- Scientific Skills:
  - Numerical Simulation
  - Numerical Analysis
  - PDEs
  - ML
  - NN
  - Bayesian Inference
  - Calculus of Variations and Optimal Control, Optimal transportation, Nonlinear and Convex Optimization
  - Multi-step methods, Runge-Kutta, Finite Difference, Finite Element, and Finite Volume methods
- Computing Skills:
  - Linux
  - Python (tensorFlow, numpy, matplotlib)
  - Matlab
  - Julia
  - C/C++
  - OpenMP/MPI
  - Latex
  - MS Word/Excel
  - VS Code
  - SPSS
- Personal Skills:
  - Ability to develop strong working relationships
  - Problem Solving
  - Adaptability
  - Decision Making
  - Fast Learner
  - Arabic Romantic Writings
  - Football

LANGUAGES

- Arabic — Native
- English — C1
- German — A2
- French — A1

MATHEMATICS TEACHER

Four years of experience in teaching Mathematics in English for intermediate and secondary classes.

Private Schools

2012 – 2018 | Beirut, Lebanon

- ## Calculus of Variations and Optimal Control

Calculus of Variations: Necessary conditions for Global Minimizers and for local minima (Euler, Legendre, Jacobi, Weierstrass) and Problems with moving endpoints.

Optimal Control: Bolza Problem, Pontryagin's Maximum Principle, Time Optimal Control Problems, Linear Quadratic Optimal Control and Differential Riccati Equation.

- ## Project: Scientific Computing

Title: *Nonlinear Porous Medium Equation* representing "Gas transport in porous medium".
Content: Numerical methods for PDEs (Voronoi FVM) and their implementation using *Julia Programming language*, space and time discretization using **Rothe method, Implicit Euler method, ExtendableGrids.jl**, simulation results 1D and 2D cases, improve the performance using **DifferentialEquations.jl**.

- ## Project: Optimal Transport

Title: "Semi-discrete Optimal Transport"

Content: Monge and Kantorovich problems, dual problem, c-transform, Reformulation of the (DP), Convex optimization, Laguerre cells, Gradient descent algorithm, Impact of learning rate and number of iterations in the rate of convergence, Gaussian Noise.

- ## Numerical Mathematics/Analysis

One and **Multi-step methods** for the numerical solution of ODEs: Implicit and Explicit methods: Runge-Kutta, Adams-Bashforth, Adams-Moulton and BDF. Consistency, Order of convergence, Zero and Absolute stability region, A-stability, Boundary Value and Eigenvalue problems, Power method, QR decomposition, Hessenberg reduction.

- ## Numerical Methods for PDEs

Finite Elements: Interpolation Lemma, Bramble-Hilbert Lemma, A Quasi-Uniform Decomposition, Error Analysis: Aubin-Nitsche Lemma, L^2 and L^∞ Error Estimates, **Conforming and Non Conforming FE**: Strang Lemmata, Crouzeix-Raviart-Element, Polygonal Approximation of Curved Boundaries, A Posteriori Error Estimators.

- ## Stationary Linear/Nonlinear Elliptic PDEs of Second Order

First Part: Sobolev spaces, Variational problems and the associated operator equations, Monotone operators, Galerkin methods, Lax-Milgram and the theorem of Zarantonello.

Second Part: Weak and Weak* convergence, Browder-Minty's theorem for **monotone operators** and Brezis' theorem for **pseudo monotone operators**, Theory of potential operators. Apply these theories to study the stationary **Navier-Stokes equation**.

- ## Probabilistic and Bayesian Modelling in ML and AI

Maximum likelihood for exponential families, EM algorithm, Bayes inference and Gibbs sampler, conjugate priors, Markov chain Monte Carlo, Gaussian processes, Gaussian approximations to posterior densities, black box variational inference.

- ## Unsupervised ML and Python programming for ML

Analyzing a dataset, Randomness, simulation of Markov chains, LLE, t-SNE, CCA, ICA, Autoencoders, Hidden Markov Models, **Kernel machines and Deep learning:** structured predictions, Anomaly detection, etc.

Technical University

2021 - 2022 Berlin, Germany

- ## Project: Porous Media

Summarizing a paper: Homogenization based on reactive porous media flow models.
Numerical simulation: approximate using DuMu^X the *Buckley-Leverett* equation for immiscible and incompressible two-phase in 1D (relative Permeability) and 2D (Analytic and random Permeability) homogeneous porous media.

- ## Project: Fluid Mechanics

Physical and mathematical modeling for the numerical simulation.
ANSYS-FLUENT software for compressible and incompressible fluids.
elsA-ONERA software for compressible flows.

- ## Wave Propagation

Implement on $\mathbf{Matlab}$ an inverse problem to determine the nature of a propagation media using discontinuous **Galerkin approximation**.

University of Pau and Pays de l'Adour

2019 – 2020 Pau, France

- ## Finite Element Methods

"Piecewise linear finite element methods for 1D elliptic equation".
Estimate on $\mathbf{Matlab}$ the order of convergence on uniform and non-uniform meshes.

Lebanese International University

2018 – 2019 Beirut, Lebanon