BABAK MABOUDI AFKHAM

PERSONAL INFORMATION

Born on 22 March 1989

Nationality	Iranian
email	babak.maboudi@epfl.ch
phone	(M) +41 78 627 46 97

INTERESTS

Research	Fast Numerical Solutions for Parametric Partial Differential Equations, via Model Order Reduction. Developing Structure-Preserving Model-Reduction Techniques for Hyperbolic Problems.
Applied Mathematics	Model Order Reduction, Approximation Theory, Uncertainty Quantification, Inverse Problems, Machine Learning.
Pure Mathematics	Differential Geometry, Symplectic Geometry, Statistics.
Computer Science	Distributed and Parallel systems.

EDUCATION

2014-present   Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne-Switzerland

Ph.D. in Computational Mathematics and Simulation Science
Advisor: Prof. Jan S. Hesthaven
Research topic: Structure-Preserving Model-Reduction

Model order reduction Has been successful in lowering the computational complexity of large-scale elliptic and parabolic partial differential equations (PDEs). However, Model order reduction of hyperbolic PDEs remains a challenge. Symmetries, conservation laws, and invariants, that are often at the core of such systems, are often destroyed over the course of model reduction. This result in a qualitatively wrong and often unstable solution. In my thesis, we develop a model reduction routine for Hamiltonian systems that preserve the symplectic symmetry, the intrinsic symmetry of the Hamiltonian system. This is possible by constructing a basis for the reduced space that is orthogonal with respect to the symplectic differential form. We show furthermore that such a basis retains conventional convergence rates. Moreover, we generalized the method to adapt to the norms and inner products most appropriate to the problem, e.g. the natural inner product obtained from a finite element method defined on an unstructured mesh. On the other hand, since most of the systems in engineering and science appear as a dissipative perturbation of a conservative system, we generalized the method to handle dissipative forces.

On a different take, we also developed a model reduction routine that preserves the conservation of mass, conservation of momentum and conservation of energy of the Euler equation for ideal fluids and the Navier-Stokes equation.

2017-2018   Massachusetts Institute of Technology (MIT), Cambridge-United States of America

Exchange Graduate Student in Aeronautics and Astronautics
Advisor: Prof. Karen Willcox
Research topic: Energy-Preserving Model-Reduction for Euler's Equation

Conventional model order reduction routines are often unstable for hyperbolic fluid flows with strong advective terms, e.g. the Euler equation for ideal fluids. During my stay at MIT, I investigated a model reduction routine that preserves

the conservation of energy and conservation of momentum for the fluid flows. This is obtained by first discretizing the system using discrete skew-symmetric differential operators. A model reduction routine that preserves the skew-symmetry of the discrete system can then preserve the mentioned invariants. Model reduction of the combustion equation is still an ongoing project.

2012-2014   Royal Institute of Technology (KTH), Stockholm-Sweden

M.Sc. in Scientific Computing
Advisor: Prof. Anna-Karin Tornberg
Thesis topic: Simulation of elastic rods with intrinsic curvature and twist immersed in fluid

The coupling of fluid flow with elastic micro-structures often posses computational challenges. When dealing with rod-like elastic objects immersed in a fluid, one way to overcome this computational complexity is to approximate three-dimensional rods with one-dimensional curves. However, one-dimensional curves result in singularities when fluid-structure forces are evaluated. In my thesis, we regularized the immersed one-dimensional rod by discretizing it into a set of interacting regularized point forces. This method removes the singularities while providing a faster computational evolution. Furthermore, we used Ewald summation formulas to achieve a higher speedup in computing the forces exerted by the rod. Our new Ewald summation formulas, allows fast numerical evaluation of the torques exerted by the elastic structure.

Among Courses: Finite Element Method, Conservation Laws, Computational Fluid Dynamics, Mathematical Modeling, Parallel Programming and Advanced Parallel Programming for Large Scale Problems, High Performance Computing, Advanced programming for Scientific Computing, Integral Theory: Measure Theory and Functional Analysis

2007-2012   Sharif University of Technology (SUT), Tehran-Iran

B.Sc. in Theoretical Mathematics
Advisor: Prof. Mohammad Reza Razvan
Thesis topic: Learning Spectral Clustering

In my thesis, we investigated a machine learning approach for unsupervised learning of a weighted graph using graph cuts.

Among Courses: Group Theory, Ring Theory, Number Theory, Real Analysis, Complex Analysis, Regression Theory, Probability Theory, Statistics, Data Structures.

AWARDS

2017   The SNSF Doc.Mobility grant, 2017.

2014   The SMC (Stockholm Mathematics Center) award for excellent master thesis, 2014.

2013   KTH scholarship and tuition fee waiver, 2013.

PUBLICATIONS

2018   Babak Maboudi Afkham, Jan S. Hesthaven, "Structure-Preserving Model-Reduction of Dissipative Hamiltonian System", Journal of Scientific Computing (2018): 1-19

Abstract: Reduced basis methods are popular for approximately solving large and complex systems of differential equations. However, conventional reduced

basis methods do not generally preserve conservation laws and symmetries of the full order model. Here, we present an approach for reduced model construction, that preserves the symplectic symmetry of dissipative Hamiltonian systems. The method constructs a closed reduced Hamiltonian system by coupling the full model with a canonical heat bath. This allows the reduced system to be integrated with a symplectic integrator, resulting in a correct dissipation of energy, preservation of the total energy and, ultimately, in the stability of the solution. Accuracy and stability of the method are illustrated through the numerical simulation of the dissipative wave equation and a port-Hamiltonian model of an electric circuit.

2017   Babak Maboudi Afkham, Jan S. Hesthaven, "Structure-Preserving Model-Reduction of Parametric Hamiltonian System", SIAM Journal on Scientific Computing 39.6 (2017): A2616-A2644

Abstract: While reduced-order models (ROMs) have been popular for efficiently solving large systems of differential equations, the stability of reduced models over long-time integration is of present challenges. We present a greedy approach for ROM generation of parametric Hamiltonian systems that captures the symplectic structure of Hamiltonian systems to ensure stability of the reduced model. Through the greedy selection of basis vectors, two new vectors are added at each iteration to the linear vector space to increase the accuracy of the reduced basis. We use the error in the Hamiltonian due to model reduction as an error indicator to search the parameter space and identify the next best basis vectors. Under natural assumptions on the set of all solutions of the Hamiltonian system under variation of the parameters, we show that the greedy algorithm converges with exponential rate. Moreover, we demonstrate that combining the greedy basis with the discrete empirical interpolation method also preserves the symplectic structure. This enables the reduction of the computational cost for nonlinear Hamiltonian systems. The efficiency, accuracy, and stability of this model reduction technique is illustrated through simulations of the parametric wave equation and the parametric Schrodinger equation.

2018   Babak Maboudi Afkham, Ashish Bhatt, Bernard Haasdonk, Jan S. Hesthaven, "Symplectic Model Reduction with a Weighted Inner Product", Submitted to SIAM Journal on Scientific Computing

Abstract: In the recent years, considerable attention has been paid to preserving structures and invariants in reduced basis methods, in order to enhance the stability and robustness of the reduced system. In the context of Hamiltonian systems, symplectic model reduction seeks to construct a reduced system that preserves the symplectic symmetry of Hamiltonian systems. However, symplectic methods are based on the standard Euclidean inner products and are not suitable for problems equipped with a more general inner product. In this paper, we generalize symplectic model reduction to allow for the norms and inner products that are most appropriate to the problem while preserving the symplectic symmetry of the Hamiltonian systems. To construct a reduced basis and accelerate the evaluation of nonlinear terms, a greedy generation of a symplectic basis is proposed. Furthermore, it is shown that the greedy approach yields a norm-bounded reduced basis. The accuracy and the stability of this model reduction technique are illustrated through the development of reduced models for a vibrating elastic beam and the sine-Gordon equation.

2018   Babak Maboudi Afkham, Karen Willcox, Jan Hesthaven, "Energy Preserving Model Reduction of Fluid Flows" - Under Preparation

PROGRAMMING SKILLS

C/C++: LAPACK, MPI, OpenMP, CUDA. Python: FEniCS. MATLAB.
ParaView.

TEACHING AND SUPERVISION

2014-2017	Principal Teacher Assistant of Analysis I and II: Holding 8 hours of lecture, Holding Exercise classes,Designing weekly exercise sheets
2017	Co-supervisor of the master thesis: "Energy preserving model reduction of fluid dynamics", Nicolo Ripamonti
2015	Supervisor of the semester project: "Hamiltonian formulation for non-conservative systems", Bozorgmehr Aminian

INVITED TALKS AT INTERNATIONAL CONFERENCES AND WORKSHOPS

2018	MoRePaS 2018 Conference - Nantes, France Keynote: "Model Order Reduction While Preserving a First Integral"
2016	MORCIP - Workshop on Model Order Reduction for Control & Inverse Problems, EPFL Invited Speaker: "Structure-Preserving Model Reduction of Hamiltonian Systems"
2016	ALOP - Workshop on Reduced Order Models in Optimization, The University of Trier Invited Speaker: "Structure-Preserving Model Reduction of Hamiltonian Systems"

SCHOOLS AND WORKSHOPS

2016	Winter School on Uncertainty Quantification, University of Basel, Switzerland
2015	Bayesian Methods for Inverse Problems, University of Warwick, Uk.
2015	International School on Model Reduction for Dynamical Control Systems, Dubrovnik, Croatia.
2013	PDC Summer School: Introduction to High-Performance Computing, KTH, Stockholm, Sweden.

LANGUAGES

English (Professional working proficiency), Persian (Mother Tongue), French
(Intermediate Proficiency)

HOBBIES

Rock-climbing, Mountaineering (Mount Kilimanjaro 5895m, Mount Damavand
5678m), Distance Running

REFERENCES

Prof. Jan S. Hesthaven
Ecole Polytechnique Fédérale de Lausanne (EPFL)

Prof. Bernard Haasdonk
University of Stuttgart

April 5, 2018