Curriculum Vitae

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Contact Information

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Education

09/2006 – 06/2012	Ph.D., Computational Mathematics **Stanford University**, Stanford, CA, United States Advisor: Professor Charbel Farhat Co-advisors: Professor George Papanicolaou Professor Adrian Lew
09/2007 – 04/2010	M.S. Financial Mathematics **Stanford University**, Stanford, CA, United States
09/2002 – 06/2006	B.S., Mathematics **Peking University**, Beijing, China Advisor: Professor Maozhi Xu

Ph.D. Dissertation

"High-Order Embedded Boundary Methods for Fluid-Structure Interaction", Stanford University

Academic Appointment

08/2016 – present	Assistant Professor Department of Mathematical Sciences Computational Science Program **University of Texas at El Paso**, El Paso, TX, United States
10/2012 – 07/2016	Postdoctoral Associate, Computational Mechanics Group Department of Civil and Environmental Engineering **Duke University**, Durham, NC, United States

Honors & Awards

2015	Travel award of the 13rd US National Congress on Computational Mechanics
2011	Finalist of the **3rd BGCE Student Paper Prize**, organized by SIAM CS&E
2006-2009	**Stanford Graduate Fellowships** in Science and Engineering
2002-2006	**Hong Kong Mingde Fellowship** at Peking University
2002	**Gold Medal** in International Mathematical Olympiad, Glasgow, Scotland
2002	**Gold Medal** in Mathematical Olympiad in China, Shanghai, China
2001	**Gold Medal** in National Bulgarian Mathematical Olympiad, Sofia, Bulgaria

Research Interests

- Numerical analysis of PDEs, hyperbolic conservation laws
- Multi-physics problems, mathematical and numerical modeling of inelastic materials
- Scientific computing, high performance computing
- Shock hydrodynamics, aerodynamics, biomechanics, geophysics

Current Research

- **The dynamic variational multiscale (D-VMS) analysis in computational mechanics**

Many PDEs that arise in transient fluid and solid dynamics exhibit high stiffness or strong convection phenomenon, when the classical Galerkin method often fails. The VMS analysis, originally designed for time-independent equations, provides a theoretical framework to construct stabilized methods for these problems. We extended the methodology to time-dependent PDEs in several contexts. These include fluid dynamics on moving grids, strong shocks in Lagrangian coordinates, dynamics of nearly incompressible elastic and inelastic solids, and coupled fluid-solid systems. More importantly, the proposed methods work well with both tensor-product grids and simplicial grids, and they prove to be second-order accurate and energy stable when applied with piecewise linear finite element approximations.

- **High-order numerical methods for hyperbolic conservation laws**

We developed a class of high-order numerical methods for solving nonlinear hyperbolic conservation laws. These methods are of mixed variable type, in the sense that we use both nodal values and cell-averaged values to construct discrete differential operators, which closely resemble that obtained by Hermite interpolations. Peculiar properties of the proposed methods include one-order higher spatial accuracy in the numerical solutions than the designed order of the convective operator, and two-order higher for the diffusive one (if appears at all). This is contrary to existing finite difference or finite volume methods, in which case, for example, a first-order discretization of the advection term leads to a first-order method. The methods are shown to be energy stable without any other stabilization, and we combine them with the entropy viscosities to capture strong discontinuities such as shocks.

- **Embedded boundary methods for free boundary problems**

For problems with free boundaries or moving material interfaces, the embedded boundary methods (EBM) have advantage over schemes using body-fitted grids in handling large boundary motion and topological changes. However, conventional EBMs are typically inconsistent near the boundary when the motion is large, which leads to the loss of accuracy at these locations. To address this issue, we developed a systematic procedure to enhance any preferred PDE solver with proper treatments near the moving boundary so that the formal order of accuracy of the chosen method is preserved. We applied this procedure, called operator matching method, to construct a third-order numerical method for advection equation with moving boundary conditions, and a second-order method for fluid dynamics in the context of fluid-fluid and fluid-structure interactions.

Professional Memberships

- Society for Industrial and Applied Mathematics (SIAM)
- American Mathematical Society (AMS)
- United States Association for Computational Mechanics (USACM)
- American Institute of Aeronautics and Astronautics (AIAA)

Services

- Conference session chair
  Session: Numerical algorithms for inviscid and viscous flows
  21st AIAA Computational Fluid Dynamics Conference, San Diego, CA. June 2013
- Invited reviewer
  Journal of Computational Physics
  Mathematical Modelling and Numerical Analysis
  International Journal for Numerical Methods in Fluids
  International Journal for Numerical Methods in Engineering
  Engineering Optimization

Journal Publications

1. G. Scovazzi, T. Song, and **X. Zeng**, "A velocity/stress mixed stabilized nodal finite element for elastodynamics: Analysis and computations with strong and weak boundary conditions", (*Submitted*)
2. **X. Zeng**, "A General Approach to Enhance Slope Limiters in MUSCL Schemes on Non-Uniform Rectilinear Grids", *SIAM J. Sci. Comput.* 38 (2016) A789–A813
3. **X. Zeng** and G. Scovazzi, "A variational multiscale finite element method for monolithic ALE computations of shock hydrodynamics using nodal elements", *J. Comput. Phys.* 315 (2016) 577–608
4. G. Scovazzi, B. Carnes, **X. Zeng**, and S. Rossi, "A simple, stable and accurate tetrahedral finite element for transient, nearly incompressible, linear and nonlinear elasticity: A dynamic variational multiscale approach", *Int. J. Num. Meth. Eng.* 106 (2016) 799–839
5. A. Main, **X. Zeng** and C. Farhat, "An enhanced FIVER method for multi-material flow problems with second-order convergence rate" (*Submitted*)
6. G. Scovazzi, **X. Zeng**, and S. Rossi, "Variational multiscale methods for nearly and fully incompressible transient dynamics computations: Design principles and lessons learned" (*Preprint*)
7. **X. Zeng** and G. Scovazzi, "The dynamic variational multiscale approach for transient, linear and nonlinear viscoelasticity using tetrahedral finite elements" (*Preprint*)
8. **X. Zeng**, "A Hybrid FD-FV Method for One-Dimensional First-Order Hyperbolic Conservation Laws" (*Submitted*)
9. **X. Zeng** and G. Scovazzi, "Extension of the D-VMS approach to transient dyanmics of linear and nonlinear orthotropic materials" (*Preprint*)
10. **X. Zeng** and G. Scovazzi, "A frame-invariant vector limiter for flux corrected nodal remap in arbitrary Lagrangian–Eulerian flow computations", *J. Comput. Phys.* 270 (2014) 753–783
11. **X. Zeng**, "A High-Order Hybrid Finite Difference-Finite Volume Approach with Application to Inviscid Compressible Flow Problems: A Preliminary Study" *Comput. Fluids* 98 (2014) 91–110
12. **X. Zeng** and C. Farhat, "A Systematic Approach for Constructing Higher-Order Immersed Boundary and Ghost Fluid Methods for Fluid-Structure Interaction Problems", *J. Comput. Phys.* 231 (2012) 2892–2923

Conference Proceedings

1. **X. Zeng**, “A Hybrid Finite Difference-Finite Volume Approach and Its Applications to Inviscid Compressible Flows”, 21st AIAA Computational Fluid Dynamics Conference, San Diego, California, June 24-26, 2013
2. **X. Zeng** and C. Farhat, “A Systematic Procedure for Achieving Higher-Order Spatial Accuracy in Ghost Fluid and Other Embedded Boundary Methods for Fluid-Structure Interaction Problems”, 20th AIAA Computational Fluid Dynamics Conference, Honolulu, Hawaii, June 27-30, 2011

Conference Talks

1. **X. Zeng**, K. Li, and G. Scovazzi, “A VMS-FEM for monolithic ALE computations of shock hydrodynamics”
   Session: Computational Fluid Dynamics
   2016 SIAM Annual Meeting, Boston, MA. Jul. 2016
2. **X. Zeng** and G. Scovazzi, “A Variational Multisale Approach for Transient Dynamics of Viscoelastic Materials Using Linear Tetrahedral Finite Elements”
   Session: Advanced Finite Elements for Complex-Geometry Computations: Tetrahedral Algorithms and Related Methods
   13th US National Congress on Computational Mechanics, San Diego, CA. Jul. 2015
3. **X. Zeng** and G. Scovazzi, “A Variational Multi-Scale Approach Using Linear Simplicial Finite Elements for Transient Viscoelastic Solid Mechanics”
   Session: FEM for Fluids and Structures
   2015 SIAM Conference on Computational Science and Engineering, Salt Lake City, UT. March 2015
4. **X. Zeng** and G. Scovazzi, “A Flux-Corrected Remap of Vector Fields for ALE Hydrodynamics with Nodal Elements”
   Session: Godunov Techniques and Slope Limiters in Lagrangian and ALE Hydrodynamics
   11th World Congress on Computational Mechanics, Barcelona, Spain. July 2014
5. **X. Zeng**, “A Hybrid FD-FV Method for First-Order Hyperbolic Systems”
   Session: Numerical Methods in PDE
   2014 SIAM Annual Meeting, Chicago, IL. July 2014
6. **X. Zeng**, “A High-Order Hybrid FD-FV Method for Inviscid Flow Problems”
   Session: High-Order Methods for Computational Fluid Dynamics
   12th US National Congress on Computational Mechanics, Raleigh, NC. July 2013
7. **X. Zeng**, “A Hybrid Finite Difference-Finite Volume Approach and Its Applications to Inviscid Compressible Flows”
   Session: Numerical Algorithms for Inviscid and Viscous Flows
   21st AIAA Computational Fluid Dynamics Conference, San Diego, CA. June 24-6, 2013
8. **X. Zeng** and C. Farhat, “A Systematic Procedure for Achieving Higher-Order Spatial Accuracy in Ghost Fluid and Other Embedded Boundary Methods for Inviscid Compressible Flow in Fluid Structure Interaction Problems” (***Keynote presentation***)
   Session: Computational Fluid Mechanics for Free and Moving Boundaries
   11th US National Congress on Computational Mechanics, Minneapolis, MN. July 2011
9. **X. Zeng** and C. Farhat, “A Systematic Procedure for Achieving Higher-Order Spatial Accuracy in Ghost Fluid and Other Embedded Boundary Methods for Fluid-Structure Interaction Problems”
   Session: Immersed-Boundary and Interface-Tracking Methods
   20th AIAA Computational Fluid Dynamics Conference, Honolulu, HI. June 2011

10. **X. Zeng** and C. Farhat, "Improved Limiter Functions in MUSCL Schemes on 1D Non-uniform Grids"
The Third BGCE Student Prize finalist presentation
SIAM Conference on Computational Science and Engineering, Reno, NV. February 2011

Invited Talks

1. **X. Zeng**, "A Dynamic Variational Multiscale Finite Element Method for Transient Solid Mechanics"
Richard F. Barry Colloquium, Department of Mathematics and Statistics,
Old Dominion University, Norfolk, VA, Sept., 2015
2. **X. Zeng**, "A Variational Multiscale Finite Element Method for Transient Solid Mechanics using Linear Simplicial Elements"
Recent Advances in Applied and Computational Mathematics,
Huazhong University of Science and Technology, Wuhan, China, May, 2015
In celebration of the 60th birthday of Russel Caflisch
3. **X. Zeng**, "A Frame-Invariant Vector Limiter for FCT-Remap in ALE Flow Computations"
Department of Mechanical Engineering and Material Science,
Duke University, Durham, NC, Feb. 2014
4. **X. Zeng**, "A Systematic Approach for Constructing Higher-Order Embedded Boundary Methods for Flows in Multi-Material Systems"
Department of Mechanical Engineering and Material Science,
Duke University, Durham, NC, Jan. 2014
5. **X. Zeng**, "A Systematic Approach for Constructing Higher-Order Embedded Boundary Methods for Moving Boundary Problems and Fluid-Structure Interactions"
Division of Mathematics and Computer Science,
Argonne National Laboratory, Chicago, IL, Dec. 2012

Teaching Assistants

2010-2011 Spring	Numerical Solution of Partial Differential Equations Instructor: Professor Pierre Garapon. • Designed numerical assignments in one and multiple dimensions • Provided reviews of preliminary in mathematics and implementation instructions in semiweekly TA sessions • Helped with designing midterm and final exams
2010-2011 Winter	Partial Differential Equations in Engineering Instructor: Professor Eric Shaqfeh. • Designed and delivered review lectures in analytical methods for solving partial differential equations in weekly TA sessions
2010-2011 Autumn	Linear Algebra with Application to Engineering Computations Instructor: Professor Margot Gerritsen. • Led workshop for the whole class on the steepest descent method • Designed and delivered review lectures in fundamentals of linear algebra and matrix computation in weekly TA sessions