FEDERICO FUENTES

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EDUCATION

The University of Texas at Austin, Austin, TX, USA
Ph.D. in Computational Science, Engineering and Mathematics, expected May 2018
Option: Computational and Applied Mathematics

Various applications of discontinuous Petrov-Galerkin (DPG) finite element methods
Committee: Leszek Demkowicz (supervisor), Ivo Babuška, Luis A. Caffarelli, Thomas J. R. Hughes, J. Tinsley Oden, Aleta Wilder

Imperial College London, London, UK
M.Sc. in Advanced Computational Methods for Aeronautics, Flow Management and Fluid-Structure Interaction, 2013
Honors: Distinction, Best Overall M.Sc. Student, Best M.Sc. Research Project

Global stability of plane Couette flow using sum of squares techniques
Supervisor: Sergei Chernyshenko

Universidad de los Andes, Bogotá D.C., Colombia
B.Sc. in Mathematics, 2012
Honors: Graduated first in class

B.Sc. in Mechanical Engineering, 2012
Minor: Biomedical Engineering
Honors: Graduated first in class

RESEARCH INTERESTS

Numerical analysis, functional analysis, solid mechanics, fluid mechanics, hydrodynamic stability, finite element methods, computational mechanics, function spaces.

RESEARCH EXPERIENCE

Geophysical Fluid Dynamics Program, WHOI, Woods Hole, MA, USA, Jun.-Aug. 2017

- **Global stability of 2D plane Couette flow** (with David Goluskin)
  Improved the lower bound for the global stability limit of (spanwise-independent) 2D plane Couette flow to a value beyond the energy stability limit (first progress in 110 years) by finding a Lyapunov function to the Navier-Stokes equations with a novel semidefinite program (SDP) having sum-of-squares polynomial constraints.

The University of Texas at Austin, Austin, TX, USA, 2013-2016 (with Leszek Demkowicz)

- **High-order exact sequence shape functions**
  Constructed arbitrary high-order compatible affine-invariant shape functions approximating the standard exact sequence Sobolev spaces H^1, $H(\text{curl})$, $H(\text{div})$ and L^2 for hexahedra, tetrahedra, triangular prisms and pyramids. Resulting code freely available online.
- **DPG and DLS finite element methodologies**
  Studied discontinuous Petrov-Galerkin (DPG) finite element methods, which are very general minimum residual numerical methods especially crafted to produce stable discretizations of linear

partial differential equations. As an outgrowth, developed discrete least squares (DLS) methods, aimed at ill-conditioned problems.

- **PolyDPG: high-order polygonal finite element methods**
  Developed high-order polygonal discontinuous Petrov-Galerkin (PolyDPG) methods using so-called ultraweak formulations. They are automatically stable, accept arbitrary distortion-tolerant polygonal elements, and have a natural a posteriori error estimator for adaptivity. Code freely available online.
- **Different variational formulations of linear elasticity**
  Proved simultaneous well-posedness of a family of variational formulations of linear elasticity and numerically solved the corresponding stable minimum residual discretizations. Coupled different formulations in the same domain and demonstrated the resulting stability, allowing for flexibility in solving high-contrast multi-material problems, such as sheathed hoses or stents inside an artery.
- **Validation of DMA viscoelastic experiments**
  Completed validation of DMA calibration experiments using theoretical models (computationally solved using the DPG methodology) of time-harmonic viscoelastic thermoset materials.
- **Boundary traces of Sobolev spaces**
  Explored Lipschitz boundary trace theorems involving fractional Sobolev spaces associated to differential forms in 3D de Rahm exact sequences.

Imperial College London, London, UK, 2012-2013 (with Sergei Chernyshenko)

- **Global stability of fluids via sum-of-squares optimization**
  Wrote the incompressible Navier-Stokes perturbation equations as an uncertain dynamical system with uncertain terms having polynomial bounds. Finding a globally stable Reynolds number (implying that any perturbation will eventually decay) was reformulated as a semidefinite program (SDP) with sum-of-squares polynomial constraints. Found general methods to explicitly setup this optimization problem for (spanwise-independent) 2D plane Couette flow.

Universidad de los Andes, Bogotá D.C., Colombia, 2006-2012

- **Isogeometric analysis in hyperelastic materials** (with Victor Calo)
  Coded several nonlinear hyperelastic models in the PETSc-based software PetIGA.
- **Contour dynamics in bounded domains** (with José R. Toro)
  Solved the evolution of 2D constant vorticity contour dynamics in bounded domains using two different computational methods.
- **Second order differential operators** (with Monika Winklmeier)
  Studied the theory of distributions and Sobolev spaces as it relates to elliptic second order densely-defined differential operators with Dirichlet boundary conditions.
- **Duct fitting losses** (with Omar López)
  Participated with the Computational Mechanics group in the ASHRAE CFD Shootout contest in the prediction of duct fitting losses using CFD.
- **Wind tunnel experiments on prototype of *Triplaris americana* seed** (with Álvaro Pinilla)
  Worked in wind tunnel with a scaled-up prototype of the *Triplaris americana* flying seed.

Leibniz Universität Hannover, Hannover, Germany, May-Aug. 2009

- **Aerodynamics of the *Triplaris americana* seed** (with Jörg Seume and Alejandro Gómez)
  Investigated the flow around the rotating flying seed of the *Triplaris americana* species, using experimental measurements of the geometry and input parameters along with CFD simulations in ANSYS CFX.

TEACHING EXPERIENCE

The University of Texas at Austin, Austin, TX, USA, 2013-2016

Teaching Assistant

Numerical Methods for Applications, Todd Arbogast
Undergraduate course in which I was responsible for only one course unit: trigonometric polynomial approximation and the fast Fourier transform. Regarding this topic, I taught three 50-minute lessons, designed and graded the relevant homework, and created one exam problem.

Functional Analysis in Theoretical Mechanics, Leszek Demkowicz
Postgraduate course covering logic, topological and metric spaces, and an introduction to modern concepts in functional analysis and linear operator theory. Conducted recitation sessions, taught a lecture, held office hours, graded homework and exams.

Introduction to Mathematical Modeling in Science and Engineering, Robert Moser
Postgraduate course covering elements of classical mechanics, physics, chemistry, and biology needed to begin work in computational engineering and sciences, including continuum and quantum mechanics. Prepared weekly recitation sessions, held office hours and graded homework.

Professional Development

College of Natural Sciences Graduate Concentration in Undergraduate Teaching and Mentoring
A series of three courses that provide an introduction to evidence-based teaching in STEM fields, a practical experience in curriculum design and teaching, and training in effective mentoring.

Teaching Preparation Certificate for Teaching Assistants
Three seminar sessions aimed at fostering self-directed learning in students, grading management and developing a teaching identity.

Inclusive Classrooms Leadership Certificate Seminar
Two sessions in developing classroom inclusivity.

Student Employee Excellence Certificate
Six workshops covering ethics, professionalism, and effective communication, and a written reflection on future as a teacher.

Universidad de los Andes, Bogotá D.C., Colombia, 2006-2012

Teaching Assistant

Integral Calculus and Differential Equations, Luis Jaime Corredor
Taught problem and review sessions twice a week, graded homework twice a week, created and graded quizzes, monitored class participation, and held office hours.

Integral Calculus and Differential Equations, Monika Winklmeier
Lectured problem and review sessions twice a week, partially created and graded homework, quizzes and exams, monitored class participation, and held office hours.

AWARDS AND HONORS

- Geophysical Fluid Dynamics Fellowship, Woods Hole Oceanographic Institute (WHOI), 2017
- Professional Development Award, The University of Texas at Austin, 2017
- Graduate School Recruitment Fellowship, The University of Texas at Austin, 2013
- Robert Bird Group award for Best M.Sc. Research Project, Department of Aeronautics, Imperial College London, 2013
- Best Overall M.Sc. Student, Department of Aeronautics, Imperial College London, 2013
- COLFUTURO Scholarship Recipient for Colombian postgraduates studying overseas, 2012
- Graduated top of the class in B.Sc. in Mathematics, Universidad de los Andes, 2012

- Graduated top of the class in B.Sc. in Mechanical Engineering, Universidad de los Andes, 2012
- Among Best Saber Pro Scores (nationwide exam for all Colombian university graduates), 2011
- Semester Academic Excellence Scholarships (best semester GPAs, roughly in top 0.3% among 10000 students), Universidad de los Andes, 2007, 2010, 2011 (on separate occasions)
- Ramón de Zubiría Scholarship (best cumulative GPA, roughly in top 0.15% among 10000 students, covered full year), Universidad de los Andes, 2009
- Medal for top 5 in the XXIV Colombian Mathematics Olympics (among 24000 participants), 2005

TECHNICAL SKILLS

- MATLAB, Fortran, Python, VBA, Java
- ANSYS, SOLIDWORKS, Solid Edge
- LaTeX, Sublime, Ipe, ParaView, matplotlib
- Linux, Windows and Mac
- Bash, makefiles, compilers (intel and GNU), version control systems (Git, SVN)
- Software developer for (see also github.com/federicofuentes):
  - In-house adaptive 2D and 3D high-order finite element codes called *hp2d* and *hp3d*
  - ESEAS high-order shape functions library
  - PolyDPG codes for polygonal finite element methods (www.polydpg.com)
  - In-house fluid stability codes using semidefinite programming

LANGUAGES

Fluent in English and Spanish.

PROFESSIONAL AFFILIATIONS

Society for Industrial and Applied Mathematics (SIAM)
American Physical Society (APS)

ACADEMIC SERVICE

Host of the ICES Babuška Forum at the University of Texas at Austin, 2017
Reviewer for *Computers & Mathematics with Applications*

PUBLICATIONS

Journal Articles

- Vaziri Astaneh, A., Fuentes, F., Mora, J., and Demkowicz, L. (2017). High-order polygonal discontinuous Petrov-Galerkin (PolyDPG) methods using ultraweak formulations. *Comput. Methods Appl. Mech. Engrg.*, 332:686-711.
- Keith, B., Petrides, S., Fuentes, F., and Demkowicz, L. (2017). Discrete least-squares finite element methods. *Comput. Methods Appl. Mech. Engrg.*, 327:226-255.
- Fuentes, F., Demkowicz, L., and Wilder, A. (2017). Using a DPG method to validate DMA experimental calibration of viscoelastic materials. *Comput. Methods Appl. Mech. Engrg.*, 325:748-765.
- Fuentes, F., Keith, B., Demkowicz, L., and Le Tallec, P. (2017). Coupled variational formulations of linear elasticity and the DPG methodology. *J. Comput. Phys.*, 348:715-731.
- Keith, B., Fuentes, F., and Demkowicz, L. (2016). The DPG methodology applied to different variational formulations of linear elasticity. *Comput. Methods Appl. Mech. Engrg.*, 309:579-609.
- Huang, D., Chernyshenko, S., Goulart, P., Lasagna, D., Tutty, O., and Fuentes, F. (2015). Sum-of-squares of polynomials approach to nonlinear stability of fluid flows: an example of application. *Proc. R. Soc. A*, 471(2183).
- Fuentes, F., Keith, B., Demkowicz, L., and Nagaraj, S. (2015). Orientation embedded high order shape functions for the exact sequence elements of all shapes. *Comput. Math. Appl.*, 70(4):353-458.

Conference Papers

- Bernal, L. M., Calo, V. M., Collier, N., Espinosa, G. A., Fuentes, F., and Mahecha, J. C. (2013). Isogeometric analysis of hyperelastic materials using PetIGA. *Procedia Computer Science*, 18:1604-1613. 2013 International Conference on Computational Science (ICCS).

In preparation

- Fuentes, F., Goluskin, D., and Chernyshenko, S. Global stability of 2D plane Couette flow beyond the energy stability limit.
- Fuentes, F. and Demkowicz, L. Lipschitz boundary trace theorems in fractional H^s(curl) spaces.

ORAL AND POSTER PRESENTATIONS

Talks

- Global stability of plane Couette flow beyond the energy stability limit. 70th Annual Meeting of the American Physical Society Division of Fluid Dynamics. Denver, CO, USA, November, 2017.
- Insulation integrity for power-dense, medium voltage, electric machinery (with Aleta Wilder). Office of Naval Research (ONR) Peer Review in Controls, Electromagnetism, and Power Electronics. Naval Postgraduate School, Monterey, CA, USA, November, 2017.
- Discrete least-squares (DLS) and polygonal discontinuous Petrov-Galerkin (PolyDPG) finite element methods. Third Minimum Residual and Least Squares Finite Element Methods Workshop. Portland State University, Portland, OR, USA, October, 2017.
- Global stability of 2D plane Couette flow beyond the energy stability limit. Texas Applied Mathematics and Engineering Symposium (TAMES). The University of Texas at Austin, Austin, TX, USA, September, 2017.

- Global stability of two-dimensional plane Couette flow beyond the energy stability limit. 2017 Geophysical Fluid Dynamics Program. Woods Hole Oceanographic Institute (WHOI), Woods Hole, MA, USA, August, 2017.
- Various applications of the DPG methodology. Oberwolfach Seminar: Discontinuous Petrov-Galerkin Methods. Mathematisches Forschungsinstitut Oberwolfach (MFO, Oberwolfach Research Institute for Mathematics), Oberwolfach, Germany, June, 2017.
- Using discontinuous minimum residual methods to simulate DMA experiments in linear viscoelasticity. 2017 Finite Element Rodeo. University of Houston, Houston, TX, USA, March, 2017.
- Using discontinuous minimum residual methods to validate DMA experimental calibration results in linear viscoelasticity. SIAM Conference on Computational Science and Engineering (CSE) 2017. Atlanta, GA, USA, February-March, 2017.
- Minimum residual methods applied to linear thermoviscoelasticity. The Mathematics of Finite Elements and Applications (MAFELAP) 2016. Brunel University London, London, UK, June, 2016.
- Minimum residual methods in linear thermoviscoelasticity. 2016 Finite Element Rodeo. Texas A&M University, College St., TX, USA, March, 2016.
- The DPG methodology applied to various variational formulations of linear elasticity. Second Minimum Residual and Least Squares Finite Element Methods Workshop. Delft University of Technology, Delft, Netherlands, November, 2015.
- High Order Shape Functions for Exact Sequence Elements of All Shapes. Part II. Pyramid. 13th U.S. National Congress on Computational Mechanics (USNCCM). San Diego, CA, USA, July, 2015.
- High Order Shape Functions for Exact Sequence Elements of All Shapes. Part II. Pyramid. 2015 Finite Element Rodeo. Southern Methodist University, Dallas, TX, USA, February, 2015.

Posters

- Using discontinuous minimum residual methods to validate DMA experiments of viscoelastic materials. Workshop for Advances in Computational Sciences and Engineering (Oden 80 years). The University of Texas at Austin, Austin, TX, USA, March, 2017.
- Minimum residual methods in linear thermoviscoelasticity. Workshop for Advances in Mathematics for Finite Elements (Babuška 90 years). The University of Texas at Austin, Austin, TX, USA, March, 2016.
- Pyramid High Order Exact Sequence Shape Functions. Polytopal Element Methods in Mathematics and Engineering. Georgia Institute of Technology, Atlanta, GA, USA, October, 2015.
- Pyramid High Order Exact Sequence Shape Functions. Advanced Numerical Methods in the Mathematical Sciences. Texas A&M University, College St., TX, USA, May, 2015.
- Orientation Embedded Finite Element (FE) Shape Functions for the Exact Sequence Elements of All Shapes. Sixth International Workshop on High-Order Finite Element and Isogeometric Methods (HOFEIM). Frauenchiemsee Island, Germany, July, 2014.