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Jesús Bonilla de Toro

Education

2015–19 **PhD in Computational Mechanics**, *Universitat Politècnica de Catalunya*, (Official title name: Doctorate in Civil Engineering).

2013–15 **MSc in Numerical methods in Engineering**, *Universitat Politècnica de Catalunya*, GPA: 9.1/10, equivalent to US GPA: 3.85/4.00.

2009–13 **Bachelor in Mechanical Engineering**, *Universitat Politècnica de Catalunya*, GPA: 9.2/10, equivalent to US GPA: 3.76/4.00, rank: 1st.

Experience

2021–present **Postdoctoral researcher**, *Los Alamos National Laboratory*, Los Alamos, US.
Currently, I am working as a postdoctoral researcher in Dr. Tang's research group. The main goal of my current research is the development of finite element methods able to simulate disruptions in Tokamak devices using fluid models of plasma. As a first step, we pretend to use visco-resistive MHD models. We are also interested in extending the results to multi-fluid models. Finally, we will pursue the simulation of disruption mitigation techniques using novel stabilization techniques developed during my PhD thesis work and similar techniques. To this end, we make use of Drekar, an HPC code developed in Sandia National Laboratories and lead by Prof. Shadid. During this time, extensive collaboration with Drekar development team has been made towards the usage and development of the code.

2020 **Postdoctoral researcher**, *Centre Internacional de Mètodes Numèrics a l'Enginyeria*, Barcelona, Spain.
After my PhD I continued in Prof. Badia's research group. I pursued the extension of my thesis results to Keller-Segel chemotaxis model. In addition, I collaborated with CIEMAT–LNF (Spanish National Fusion Laboratory) in a project for developing an inductionless incompressible MHD code for the simulation of coolant flows in Tokamak breading blankets. For developing the codes in both lines of research I used Gridap.jl Julia package. Gridap.jl is an open source FEM library developed at the research group, and lead by F. Verdugo and S. Badia. The developed code for inductionless MHD, GridapMHD.jl, is also publicly available at Github.

2018 **Visiting PhD student**, *Visitor at CSRI, Sandia Nantional Laboratories, from 2/15/18 to 8/15/18*, Albuquerque.

During this visit, I collaborated with Prof. Shadid's group. I embedded with the development team, attended team meetings, gave technical presentations on my work and also engaged in some development directly with the team and their advanced MHD/plasma physics code, Drekar.

We developed (and implemented in Drekar) a differentiable local bound preserving finite element scheme for first order hyperbolic problems. The results have been collected in a CCR summer student proceeding. A continuing collaboration has lead to a paper that was just published in Computer Methods in Applied Mechanics and Engineering.

I also successfully contributed to tasks that the group was pursuing. In particular, I helped with the assessment and implementation of stabilization techniques for anisotropic diffusion problems for magnetohydrodynamics (MHD), and for multifluid plasma models. Additionally, I worked on projections of transient and source terms for AFC stabilization for the multifluid plasma systems. In addition, I also helped in the implementation of outflow boundary conditions that included flow and thermal fluxes.

2015–19 **Pre-doctoral Researcher**, *Universitat Politècnica de Catalunya*, Barcelona.

See description below.

2014–19 **Pre-doctoral Researcher**, *Centre Internacional de Mètodes Numèrcis a l'Enginyeria (CIMNE)*, Barcelona, Spain.

I did my PhD studies at CIMNE and UPC in Prof. Badia's research group. During this time, I implemented the main results of my MSc and PhD thesis in FEMPAR software project (see description in Theses section). In addition, I also helped in the implementation of core parts of the library, e.g. arbitrary order integration rules, spline-based discretizations.

FEMPAR is an open-source finite element library for high performance computing written in object oriented Fortran (2008 standard). It handles finite element methods, discontinuous Galerkin methods, XFEM, and spline-based discretizations. Moreover, it provides highly scalable numerical linear algebra solvers. Actually, after showing perfect weakly scalability for almost half a million cores, it was included in the High-Q club, a list of the most scalable European codes.

2012–14 **Researcher (Intern)**, *Fundació CTM Centre Tecnològic, Simulation and Innovative Design department*, Manresa, Spain.

At CTM I worked in a material engineering research project. In particular, I helped in the construction and its latter experimentation of a prototype for metal atomization. I also was responsible of the powder characterization. In addition, I also worked in the simulation of parts of this process using commercial simulation software (ANSYS Fluent).

2010–12 **Intern**, *Universitat Politècnica de Catalunya, Applied Mathematics department*.

During this time I assisted professors in the preparation of different subject materials, e.g. exercises lists, exams, online tests, among others.

Vocational

2016–18 **Organizer**, *JIPI Conference*, Barcelona.

Jornades d'Investigadors Predoctorals Interdisciplinaries (JIPI) is the meeting point for all predoctoral researchers in Catalonia of all academic fields. My tasks included web maintenance and fundraising, as well as general coordination in the last years. The event is held in the Barcelona University and every year it welcomes around 300 attendants plus 80 contributors.

Theses

PhD thesis 2019

title Monotonicity-preserving finite element methods for hyperbolic problems.

advisor Santiago Badia Rodríguez

description This work is devoted to the analysis and extension of the current state of the art in monotonicity preserving finite element (FE) methods for implicit time integrators. The first part contains novel methods developed for linear scalar problems, such as first-order transport, convection-diffusion, and Burgers' equations. In the first contribution, we developed a continuous Galerkin FE method that preserves monotonicity of the solution in arbitrary meshes. Moreover, it is proven to be Lipschitz continuous, thus assuring non-linear convergence of a fixed point iteration scheme. Additionally, a differentiable version is developed, which greatly enhance the nonlinear convergence. In the subsequent contributions, this scheme is extended to isogeometric analysis. Then, it is extended to first order hyperbolic problems using current state-of-the-art techniques in algebraic flux correction. Finally, these techniques are extended to adaptive mesh refinement using hierarchically refined octree-based meshes. Moreover, a novel refinement criterion, based on the stabilization terms, is proposed.

MSc thesis 2015

title Implementation of Finite Element Solvers for the Compressible Navier-Stokes Equations.

advisor Santiago Badia Rodríguez

description In this work, the current state-of-the-art of stabilized finite element methods for solving the compressible Navier-Stokes equations was studied. We implemented, assessed, and compared residual based stabilization methods for two different sets of variables. Namely, for the conservative and the entropy set of variables. For the performed benchmarks, both sets of variables showed similar accuracy. However, the entropy variables are more amenable to parallel iterative solvers. For this latter set of variables, a first order IMEX scheme was implemented and the arising algebraic system of equations was solved in parallel using domain decomposition techniques. In particular, we used a balancing domain decomposition by constraints (BDDC) preconditioner. This combination showed high algorithmic scalability for few thousands of processors. Numerical experiments showed a good behavior of the code for the compressible Navier-Stokes and Euler equations for problems with strong shocks and boundary layers.

B.S. thesis 2013

title Simulation of a water drop impact over a flat surface using finite differences.

advisors Maria Dolors Riera Colom and Gonzalo Varela Castro description In this work, the simulation of fluids with multiple free surfaces was studied, with the aim of reaching the simulation of centrifugal atomization of metallic materials in a subsequent work. The main goal of this study was to fully understand the CFD algorithms able to deal with multiple free surfaces. The first part is devoted to review the state of the art of centrifugal atomization, and CFD schemes for free surface flows. Then, a finite difference scheme, that uses the volume of fluid technique to track free surfaces, is presented and assessed as follows. On the one hand, the results were compared to laboratory experiments of the water droplet impact on a solid surface. On the other hand, the results were compared with the results of a comercial CFD code (ANSYS Fluent). Finally, the simulation of water atomization was simulated using Fluent and validated performing laboratory experiments.

Honors, awards & grants

2015 "la Caixa" Fundation PhD scholarship (Rate of success 4%).

Languages

Catalan	Native	Spanish	Native
English	Full professional competence		

Computer skills

As introduced in the Experience section I have successfully contributed to large software projects for high performance computing. Namely, Drekar, a code based on Trilinos lead by Prof. Shadid, FEMPAR, the in-house code of Prof. Badia, and Gridap.jl the in-house FE Julia library of Prof. Badia group. At these projects I could gain experience on object oriented programming methodologies as well as parallel programming using MPI and OpenMP standards. Moreover, I have recently assisted to an introductory course in OpenACC for GPU programming organized by the Barcelona Supercomputing Center. Finally, it is worth mentioning that I am familiar with best software development practices, e.g. continuous integration, or version control. This is an expertise that I have gained working with above teams and I am intending to continue developing.
Summary:

Fortarn OO	Advanced	C++	Intermediate
Julia	Upper-Intermediate	Python	Upper-Intermediate
Linux	Advanced user level	LaTeX	Advanced
MatLAB	Intermediate	Git	Upper-Intermediate

Publications

International peer reviewed journals

1. S. Badia and J. Bonilla, *Monotonicity-preserving finite element schemes based on differentiable nonlinear stabilization,* Computer Methods in Applied Mechanics and Engineering **313** (2017) 133–158.
2. S. Badia, J. Bonilla and A. Hierro, *Differentiable monotonicity-preserving schemes for discontinuous Galerkin methods on arbitrary meshes,* Computer Methods in Applied

Mechanics and Engineering **320** (2017) 582–605.
3. J. Bonilla and S. Badia, *Maximum principle preserving space-time isogeometric analysis*, Computer Methods in Applied Mechanics and Engineering **354** (2019) 422–440.
4. S. Badia, J. Bonilla, S. Mabuza and J. Shadid, *Differentiable local bound preserving stabilization for first order hyperbolic problems*, Computer Methods in Applied Mechanics and Engineering **370** (2020) 113267.
5. J. Bonilla and S. Badia, *Monotonicity-preserving finite element schemes with adaptive mesh refinement for hyperbolic problems.*, Journal of Computational Physics **416** (2020) 109522.

Proceedings

1. S. Badia and J. Bonilla, *Monotonicity preserving nonlinear stabilization for hyperbolic scalar problems,* Conference on the Mathematics of Finite Elements and Applications (2016).
2. S. Badia and J. Bonilla, *Finite element methods preserving maximum principles,* Finite Elements in Fluids Conference (2017).
3. S. Badia and J. Bonilla, *Monotonicity preserving finite element methods for scalar convection-diffusion problems,* European Workshop on High Order Nonlinear Numerical Methods for Evolutionary PDEs (2017).
4. J. Bonilla and S. Badia, *High-order monotonicity preserving finite element methods for scalar convection-diffusion problems,* European Conference on Numerical Mathematics and Advanced Applications (2017).
5. J. Bonilla, S. Mabuza, J.N. Shadid, and S. Badia, *On differentiable linearity and local bounds preserving stabilization methods for first order conservation law systems,* (2018).
6. J. Bonilla and S. Badia, *Monotonicity preserving stabilization for convection dominated flows, International Congress on Industrial and Applied Mathematics,* (2019).
7. J. Bonilla and S. Badia, *A positivity-preserving finite element scheme for Keller-Segel Chemotaxis model, BIRS-CMO: Bound-preserving space and time discretizations for convection-dominated problems,* (2021).

Indicators

(Google Scholar)	Citations: 83, h-index: 3, i-10: 2.
(Scopus)	Citations: 60, h-index: 3.

Supervised works

2014	**Simulació de l'atomització de metalls fosos**. *Simulation of melt metals atomization*
Degree	Master in Modelling for Science and Engineering (Universitat Autònoma de Barcelona)
Student	Gerard Corominas Auguets
Advisors	Tomàs Margalef and Jesús Bonilla
Mark	9.5 (out of 10)