**Patrick Zulian**, PhD
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Scientific collaborator and board member at the Euler Institute, Università della Svizzera italiana (USI). Researcher at UniDistance Suisse. Principal investigator of SNF and PASC projects on fluid-structure interation. My work is focused on parallel domain decomposition methods for multi-physics problems, and the development of software tools for large scale scientific computing.

## EDUCATION

**Doctor of Philosophy** at ICS - USI 2012 - 2017

- Parallel methods for the variational transfer of discrete fields between arbitrary unrelated meshes
- Geometry aware simulations. Finite elements with bijective mappings
- Lecturer and teaching assistant
- Scientific advisor: Prof. Rolf Krause

**Master's degree, Computational Science**, *summa cum laude*, at USI 2010 - 2012

**Bachelor's degree, Informatics**, *magna cum laude*, at USI 2007 - 2010

## EMPLOYMENT HISTORY

**Scientific Collaborator** at Euler institute - USI 2020 - Present

- Lecturer
- Group leader

**Postdoctoral Researcher** at UniDistance Suisse 2023 - Present

- Project lead in the design of a new BSc program in Computer Sience

**Postdoctoral Researcher** at ICS - USI 2017 - 2020

- Development of methods and software for simulations in geophysics and bio-medicine
- Thesis advisor/co-advisor
- Internship mentor for MSc and BSc students from USI and ETH Zurich
- Scientific advisor: Prof. Rolf Krause

**Visiting scientist** at Lawrence Livermore National Laboratory (LLNL) 2018

- Development of 4D adaptive mesh refinement codes for space-time simulations at CASC
- Mentor: Prof. Panayot S. Vassilevski

**Summer intern** at Lawrence Livermore National Laboratory (LLNL) 2016

- Development of parallel variational transfer of discrete fields for the open-source software library MFEM
- Application and evaluation codes with least-squares partial differential equations for algebraic multigrid methods based on spectral agglomeration
- Mentor: Prof. Panayot S. Vassilevski

## MILITARY EXPERIENCE

**Chief Operations Officer, Substitute** at Swiss Army 2020

- Assistance to hospitals (CHUV Lausanne and PSPE Chateux d'Oeux) and the ambulance service Bern for the Covid-19 pandemic

- Administration of the deployment of soldiers of the medical company 2 in the two hospitals in the canton Vaud

**Company Commander, Substitute (XO)** at Swiss Army 2015 - 2018

- Rank: First Lieutenant
- Administration and planing for the military training of a company with 130 soldiers during four week service each year
- Co-organizer, co-designer of the exercise "Valser16" and "Valser18": simulations of a major incident scenarios (with 20 patients). Joint exercise with the ambulance service (FCTSA Bellinzona and Lugano), fire department (Lugano and Monte Ceneri), military police, the cantonal hospital of Bellinzona and the cp san 2 (Swiss army medical company)

## RESPONSIBILITIES

- Project design and proposal writing for research funding
- Support for the research activities connected to research projects
- Teaching and mentoring

## APPROVED RESEARCH/DEVELOPMENT PROJECTS

- **Principal investigator** at UniDistance Suisse for PASC project. P. Zulian, E. Casartelli, L. Mangani "XSES-FSI: towards eXtreme scale Semi-Structured discretizations for Fluid-Structure Interaction" 200021_215627 (2025-2028). 50% of 462000 CHF to group Zulian
- **Principal investigator** at USI for SNF project. L. Mangani (HSLU), and P. Zulian, "Immersed Methods for Fluid-Structure-Contact-Interaction Simulations and Complex Geometries" 200021_215627 (2024-2028). 50% of 754364 CHF to group Zulian
- **Co-Principal investigator** for PASC project. T. Driesner (ETHZ), and R. Krause, *FraNetG: Fracture Network Growth* (2021-2024)
- **(co-)Principal investigator** on development projects on CSCS Piz Daint and KAUST Shaheen III

## SUPERVISION OF JUNIOR RESEARCHERS

- 1 PostDoc in Computational Science
- 1 PhD thesis in Computational Science
- 6 MSc thesis in Computational Science
- 3 BSc thesis in Informatics

## SCIENTIFIC REVIEWING ACTIVITIES

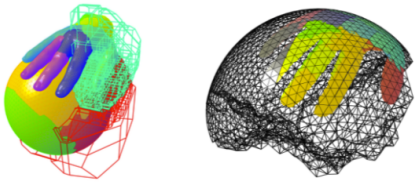
- **Reviewer** for the Journal of Computational Physics, ELSEVIER (2019-2023)
- **Reviewer** for Water Resources Research, Advancing Earth and Space Science (2021)
- **Reviewer** for Engineering analysis with boundary elements (2024)

## ORGANISATION OF CONFERENCES

- **Local conference organizer** CMIS (2026)
- **Minisymposium organizer**: SIAM CSE (2021), WCCM-APCOM (2022), IMG22 (2022,2025), IACM-COUPLED PROBLEMS (2025)
- **Co-Organizer** at 2021 FOMICS-DADSI seminars on scientific learning (Machine Learning, Neural Networks, Physics Informed Neural Networks)

# Scientific achievements

## Variational transfer and non-conforming mesh methods for multi-physics

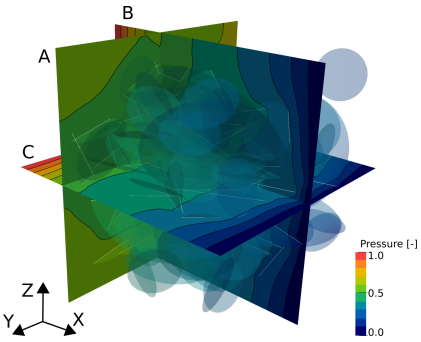


**Variational resampling** The solution of coupled multi-physics problems requires stable and efficient techniques for transferring discrete fields between non-matching volumes or surface meshes. We have developed a parallel variational resampling approach which includes a geometric-search strategy, load-balancing, and computation of the resampling operator. To our knowledge, the code is unique and has been adopted for many research projects and computational science articles ranging from geophysics to bio-medicine.

**Fluid-structure interaction (FSI)** We developed two different FSI frameworks based on variational transfer techniques. The first framework couples a finite element discretization for the structural mechanics with a high-order finite difference method for the fluid dynamics. The second framework is entirely based on finite elements and is designed to solve FSI problems with the additional challenge of simulating the contact between the immersed hyper-elastic structures.

**Multi-body contact problems** The variational resampling techniques have been expanded to include the discretization of contact conditions between multiple elastic bodies. We use the mortar method in combination with dual Lagrange multipliers. However, the MPI-based geometric search for potential contact surfaces and load-balancing can be re-purposed for other methods. Methods and codes have been fitted to the context of geophysics oriented test-cases.

## Methods and software for computational geophysics




**Flow in fractured porous media using dual Lagrange multipliers** Geological settings with reservoir characteristics include fractures with different material and geometrical properties. Hence, numerical simulations in applied geophysics demand computational frameworks that efficiently integrate various fracture geometries in a porous medium matrix. We developed methods and software for simulating single-phase flow in fractured porous media and its application to different types of non-conforming mesh models (e.g., link 1, link 2, link 3).

**Software for large scale simulation of fracture propagation** Non-linear phase field models are increasingly used to simulate fracture propagation models. The numerical simulation of fracture networks of realistic size requires the efficient parallel solution of large coupled non-linear systems. Although efficient iterative multi-level methods for these types of problems are available in principle, they are not widely used in practice due to the complexity of their parallel implementation. We developed a software which is capable of simulating 1000 2D fractures and 100 3D fractures on supercomputers.

## Open–source software libraries for scientific computing

UTOPIA

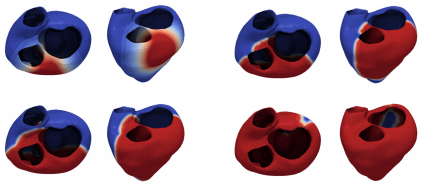
MARS Mesh Adaptive refinement for supercomputing

Creator and lead developer of three open-source libraries:

| | |
|---|---|
| **Utopia** | https://bitbucket.org/zulianp/utopia |
| **ParMoonolith** | https://bitbucket.org/zulianp/par_moonolith |
| **MARS** | https://bitbucket.org/zulianp/mars |

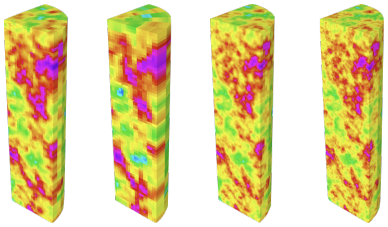
These libraries are now community software used and extended as part of different projects (e.g., PASC projects such as AV-flow, FASTER, FraNetG) actively supported and promoted by the Swiss National Supercomputing Centre (CSCS).

## Space–time finite elements



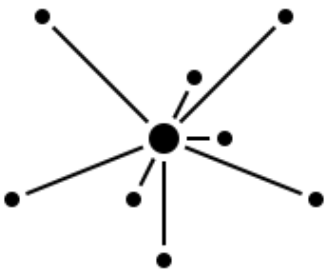
We developed space-time multilevel methods and software. In particular, we developed a (semi-)geometric multigrid for solving space-time problems discretized with finite elements combining continuous and discontinuous Galerkin methods. Our semi-geometric multigrid method allows the construction of coarse discretizations starting from any finite element mesh and automatically generating coarse meshes. Moreover, we combine the finite element spaces representing space and time dimensions by employing a tensor-product which allows for treating the spatial discretization in a standard way.
We also developed a prototype for a 4D mesh manager that adaptively discretizes the space-time domain with pentatopes.

## Multilevel methods for uncertainty quantification



We contributed to the development of a Scalable hierarchical PDE sampler for generating spatially correlated random fields using non-matching meshes. Based on the multilevel Monte Carlo (MLMC) method, we designed this sampler to quantify output uncertainties of PDEs with random input coefficients on general and unstructured computational domains.

## Collaborations



Direct contributor to collaborations involving USI/Group Krause and groups from different institutions. International-level collaborations involved the "Lawrence Livermore National Lab" (LLNL), with which the applicant collaborated in 2016 and 2018. In collaborations with "University of Torino" we developed parallel algorithms for radial basis function interpolation based on the partition of unity method. National-level collaborations involved groups from the "ETHZ Department of earth sciences", particularly the "Geothermal Energy and Geofluids" group (GEG). The active collaboration with GEG resulted in several journal articles and contributions to different conferences. Collaborations with "ARTORG Center for Biomedical Engineering Research, University of Bern" gave rise to contributions to methods for numerical simulations of fluid-structure interaction problems. An active and strict collaboration with the "Swiss National Supercomputing Centre" was born from developing and maintaining open-source libraries of hardware-portable code for modern supercomputers. Recent collaborations involve the "Competence Center of Fluid Mechanics and Hydro Machines" at HSLU and "KNF Flodos AG" for developing software tools for fluid-structure interaction, as well as "UNIL" for basic research on discretization methods.