Umberto Emanuele Villa

Contact Information

Washington University in St. Louis
Electrical & Systems Engineering
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Research Highlights

My research interests are directed towards integrating data (experiments and images) with mathematical model of physical phenomena and numerical simulations that are relevant to biomedical, biological, and engineering based problems, including electromagnetism, photon transport, porous media flow, thermodynamics, fluid-dynamics, and solid mechanics.
My areas of expertise include numerical methods for uncertainty quantification, Bayesian inference, inverse problems, computational imaging, data science, optimal design of experiments, stochastic optimization, partial differential equations (PDE), high performance computing, finite element analysis, numerical linear algebra, and multilevel methods.

Education

Emory University, Atlanta, GA (United States)
PhD in Mathematics **2012**

Politecnico di Milano, Milan (Italy) & **Politecnico di Torino**, Turin (Italy)
ASP diploma - Alta Scuola Politecnica **2008**

Politecnico di Milano, Milan (Italy) & **Politecnico di Torino**, Turin (Italy)
Dual Master's degree in Mathematical Engineering, cum laude **2007**

Politecnico di Milano, Milan (Italy)
Bachelor's degree in Mathematical Engineering, cum laude **2005**

Employment

Washington University in St. Louis, St. Louis, MO
Electrical & Systems Engineering

Research Assistant Professor **2018 –**
Imaging Science Ph.D. Program Faculty **2018 –**
Institute of Public Health Faculty Scholar **2020 –**

University of Illinois, Urbana-Champaign, IL
Department of Bioengineering

Adjunct Research Assistant Professor **2020 –**

The University of Texas at Austin, Austin, TX
Institute for Computational Engineering and Science

Research Associate **2015 – 2018**

Lawrence Livermore National Laboratory (LLNL), Livermore, CA
Center for Applied Scientific Computing

Visiting Scientist **2015 – 2021**
Postdoctoral Fellowship **2013 – 2015**
Student Internship **Summers 2011 & 2012**

Oak Ridge National Laboratory (ORNL), Oak Ridge, TN
Computer Science and Mathematics Division

Student Internship **Summers 2009 & 2010**

Honors and Awards

Best Student Paper Award, 12th Copper Mountain Conference on Iterative Methods, Copper Mountain, Colorado, US **2012**

Medal for best graduate recipient, B.S. in Mathematical Engineering, Politecnico of Milano, Milan, Italy **2005**

Competed in the national phase of the International Mathematical Olympiad, Cesenatico, Italy **2001**

Updated on April 12, 2021.

Grants and Contracts

M. Anastasio (PI) and **U. Villa (Co-I and subaward PI)**, *Advanced image reconstruction for accurate and high-resolution breast ultrasound tomography*, National Institute of Health, National Institute of Biomedical Imaging and Bioengineering, NIH R01EB028652, 09/01/19–08/31/23, $2,571,626 (WUSTL subaward amount $250,761, includes indirect costs).

U. Villa (PI), *ADLA: Automatic differentiation and local assembly of exotic finite element variational forms in MFEM*, LLNL B638337 subcontract, 11/01/19-10/31/20, $60,000.

O. Ghattas (PI) and **U. Villa (Co-PI)**, *Collaborative Research: SI2-SSI: Integrating Data with Complex Predictive Models under Uncertainty: An Extensible Software Framework for Large-Scale Bayesian Inversion*, National Science Foundation, Division of Advanced Cyberinfrastructure, Grant ACI-1550593, 09/01/16–08/31/20, $350,885. A collaborative research project with N. Petra (UC-Merced) and Y. Marzouk and M. Parno (MIT) with total funding of $1.35M.

0. Ghattas, Y. Marzouk, M. Parno, N. Petra, G. Stadler, and **U. Villa**, *2018 Gene Golub SIAM Summer School* entitled *Inverse Problems: Systematic Integration of Data with Models under Uncertainty*, Society for Industrial and Applied Mathematics, 2018, $109,200 (Funding provided by SIAM to hold a 2-week summer school on inverse problems in Breckenridge, CO, June 16–30, 2018. `http://g2s3.com/`).

Computational resources awards

M. Anastasio (PI), **U. Villa (Co-PI)**, *A computational framework integrating wave physics simulation and machine learning for fast and accurate transcranial photoacoustic tomography reconstruction*, Illinois Blue Waters research allocation, 210,000 node-hours

M. Anastasio (PI); J. Poudel, **U. Villa (Co-PI)**, *Safe and rapid functional brain imaging with transcranial photoacoustic tomography: Accelerating iterative image reconstruction algorithms using GPUs*, Illinois Blue Waters research allocation, 210,000 node-hours (estimated value of awarded resources $130,263).

U. Villa (PI), Cloud computing resources for the graduate level course on *Computational Methods in Imaging Science*, XSEDE educational allocation TG-SEE190001, 2020, 50,000 CPU hours (estimated value of awarded resources $1,000).

U. Villa (PI), Cloud computing resources for the graduate level course on *Computational Methods in Imaging Science*, XSEDE educational allocation TG-SEE190001, 2019, 50,000 CPU hours (estimated value of awarded resources $7,445).

U. Villa (PI) and N. Petra (Co-PI), Cloud computing resources for the *2018 Gene Golub SIAM Summer School* entitled *Inverse Problems: Systematic Integration of Data with Models under Uncertainty*, XSEDE educational allocation TG-DMS180009, 2018, 60,000 CPU hours (estimated value of awarded resources $10,014).

Scholarships

Laney Graduate School Scholarship, Emory University, Atlanta, GA **2008 – 2012**
Alta Scuola Politecnica Scholarship, Politecnico of Milano, Milan, Italy, **2005 – 2007**

Research Experience

Washington University in St. Louis, St. Louis, MO **2018 –**
Investigation of variational Bayesian inference methods for medical imaging, photoacustic tomography; scalable numerical methods for uncertainty quantification and inverse problems.
Projects:

- *Integrating mathematical models and data-driven approaches for Bayesian inference*
  This project aims at developing a computational framework for the solution of Bayesian inverse problems integrating physical modeling and data-driven approaches to account for model error and prior distribution of sought-after parameters.
- *Predictive modeling for computational oncology* Collaboration with D. Faghihi (The University at Buffalo)
  The overarching goal of this project is to develop computational models and algorithms to make a reliable prediction of tumor growth and patient-specific response to radiotherapy treatment, thus advancing current standard-of-care.
- *A computational framework enabling quantitative 3D optoacoustic imaging of vasculature and oxygen saturation within the human breast*
  Collaboration with M. Anastasio and A. Oraevsky (Tomowave Inc)

This project addresses the challenges of reducing over-diagnosis and over-treatment of breast cancer by developing transformative computational methods to enable three-dimensional (3D) quantitative optoacoustic tomography (OAT) of the vasculature and oxygen saturation distribution within the human breast.

- *Advanced image reconstruction for accurate and high-resolution breast ultrasound tomography*
  National Institute of Health, National Institute of Biomedical Imaging and Bioengineering (NIBIB), R01EB028652
  M. Anastasio (PI)
  The broad objective of this project is to maximize the clinical utility of ultrasound tomography (UST) for whole breast imaging by significantly advancing the state-of-the-art in UST image reconstruction methods.
  Role: **Co-Investigator/Subaward PI** (09/01/2019–08/31/2023)
- *Safe, rapid & functional pediatric brain imaging using photoacoustic computed tomography*
  National Institute of Health, National Institute of Neurological Disorders and Stroke (NINDS), R01NS102213
  L. Wang, M. Anastasio (PIs)
  The goal of this project is to develop and evaluate a safe, rapid, and functional three-dimensional (3D) pediatric neuroimaging modality based on photoacoustic computed tomography (PACT).
  Role: **Other personnel** (08/01/18–05/31/2019)

University of Texas at Austin, Austin, TX **2015 – 2018**
Investigation of scalable numerical methods for uncertainty quantification, inverse problems, PDE-constrained optimization, optimization under uncertainty, optimal design of experiments, model inadequacy.
Application of end-to-end uncertainty quantification techniques to subsurface flow, turbulent flow, combustion, biological tissues mechanics, ice-ocean interaction and wave propagation problems.
Development of a Python/FEniCS toolbox for deterministic and Bayesian inverse problems, uncertainty quantification and propagation.
Preparation of proposals, annual reports, and final research reports to government agencies, industry, universities.
Mentor: Prof. Omar Ghattas (Institute for Computational Engineering and Sciences - ICES).
Projects:

- *Integrating Data with Complex Predictive Models under Uncertainty: An Extensible Software Framework for Large-Scale Bayesian Inversion*
  National Science Foundation, Division of Advanced Cyberinfrastructure, ACI-1550593
  O. Ghattas (PI), U. Villa (Co-PI)
  The goal of this study is to develop, disseminate, and support a robust, scalable, high-performance, open-source software framework incorporating a suite of advanced Bayesian inversion algorithms.
  Role: **Co-PI** (09/01/2016–08/31/2019)
- *Bayesian Optimal Experimental Design for Inverse Scattering*
  Air Force Office of Scientific Research, Computational Mathematics program, FA9550-17-1-0190
  O. Ghattas (PI), G. Biros and Y. Marzouk (Co-PIs)
  The goal of this study is to develop a rigorous Bayesian framework to design source/receiver configuration to maximize identifiability.
  Role: research scientist (03/15/2017–08/01/2018)
- *Large-scale Inverse Problems and Uncertainty Quantification for Reservoir Modeling*
  Joint ExxonMobil-UT Energy Institute Project, UTA17-000408 (EM10480.14)
  O. Ghattas (PI), G. Biros, T. Bui-Thanh, C. Dawson (Co-PIs)
  The focus of this joint ExxonMobil–UTEI project is to develop state-of-the-art inversion and uncertainty quantification methods to reservoir models with complex features including faults.
  Role: research scientist (04/01/2017–08/01/2018)
- *Inference, Simulation, and Optimization of Complex Systems Under Uncertainty: Theory, Algorithms, and Applications to Turbulent Combustion*
  Defense Advanced Research Projects Agency, EQUiPS program, W911NF-15-2-0121
  O. Ghattas (PI), R. Moser, G. Biros, K. Willcox, M. Heinkenschloss, A. Stuart, M. Girolami, A. Philpott (Co-PIs)
  This project developed an end-to-end, integrated uncertainty quantification framework enabling us to quantify, manage, and minimize uncertainty in large scale multiscale/multiphysics problems.

Role: research scientist (09/11/2015–08/28/2017)

Lawrence Livermore National Laboratory (LLNL), Livermore, CA **2011 – 2015**
Investigation of highly parallel and scalable numerical solvers for mixed finite element discretizations: element agglomeration algebraic multigrid (AMGe), numerical upscaling.
Hybrid MPI/OPENMP implementation of scalable and efficient numerical solver for mixed finite elements discretizations based on AMGe techniques.
Investigation of stochastic models for subsurface flow problems: multilevel acceleration of Monte Carlo methods by using algebraically constructed coarse spaces (upscaled discretizations).
Development and parallel c++ implementation of stable and robust finite element discretizations and efficient solvers for oil reservoir simulation.
Mentor: Dr. Panayot Vassilevski (Center for Applied Scientific Computing - CASC).
Projects:

- *Towards Optimal Order Resilient Solvers at Extreme Scale (TOORSES)*
  DOE Office of Advanced Scientific Computing Research
  X.-S. Li (lead PI), P. Vassilevski (LLNL PI)
  This project developed large scale linear solvers and preconditioners exploiting multilevel techniques and hierarchical matrices factorizations.
  Role: postdoctoral researcher (02/15/2013–02/15/2015)
- *Scalable Multilevel UQ Concepts for Extreme-Scale Multiscale Problems*
  DOE Office of Advanced Scientific Computing Research
  Y. Efendiev (lead PI), P. Vassilevski (LLNL PI)
  The objective of this project is to develop multilevel techniques to accelerate forward and inverse uncertainty quantification (UQ) tasks involving complex multiphysics partial differential equations models.
  Role: postdoctoral researcher (02/15/2013–02/15/21015)
- *Adaptive Dimension Reduction via Coarsening and Multilevel Solvers*
  DOE Office of Advanced Scientific Computing Research
  P. Vassilevski (PI)
  This project investigates highly efficient mathematical tools to construct coarse spaces and respective coarse models that are operator-dependent and to expand the applicability of multigrid methods to very general partial differential equations, such as mixed formulations and saddle point systems. Role: Graduate research assistant (06/01/2011–12/01/2012)

Oak Ridge National Laboratory (ORNL), Oak Ridge, TN **2009 – 2010**
Development of a general optimization-based framework for multiphysics multimodel Domain Decomposition.
Application of the multi-physics framework to conjugate heat transfer and fluid structure interaction problems.
Mentor: Dr. Judith Hill (Computer Science and Mathematics division of ORNL).

Emory University, Atlanta, GA **2008 – 2012**
Analysis and implementation of a new time-adaptive algorithm for the solution of the unsteady Navier-Stokes equations.
Development of parallel and scalable block preconditioners for saddle point problems.
Application of these new numerical methods to patient specific blood flow simulations with the aim to numerically investigate pathological or clinical flow conditions (e.g. formation of aneurysms in the carotid artery, design of left ventricle assisting devices).
Development of software to analyze bouted accelerometer data for physical activity studies (collaboration with D. Salvo Dominguez and M. Pratt).
PhD Advisor: Prof. Alessandro Veneziani.

Teaching Experience

Washington University, St. Louis, Mo

Instructor of core curriculum courses for the Ph.D. program in Imaging Science

"Computational Methods in Imaging Science" **Spring 2020**

"Computational Methods in Imaging Science" **Spring 2019**

Guest lecturer for the undergraduate level courses

"Optimization" (Prof. Kamilov) **Spring 2020**

- 01/27/2020: Second order necessary and sufficient optimality conditions
- 01/29/2020: The gradient method

"Optimization" (Prof. Kamilov) **Spring 2019**

- 03/19/2019: Convergence analysis of the Conjugate Gradient method

University of Texas, Austin, TX

Instructor of the *2018 Gene Golub SIAM Summer School* on *Inverse Problems: Systematic Integration of Data with Models under Uncertainty*, June 17-30, 2018, Breckenridge, Colorado, USA (taught jointly with O. Ghattas, Y. Marzouk, M. Parno, G. Stadler)

Co-instructor for graduate course

"Computational & Variational Inverse Problems" (Prof. Ghattas) **Fall 2017**

Guest lecturer for the graduate level courses

"Finite Element Method in Geophysics" (Prof. Ghattas) **Fall 2016**

- 09/23/2016: Finite element discretization of the 1D Poisson equation using FEniCS
- 10/7/2016: Equivalence between energy formulation and boundary value problem formulation for self-adjoint operators; A numerical illustration of finite element solution convergence rates
- 11/18/2016: Finite element discretization of the 2D Poisson equation using FEniCS

"Computational & Variational Inverse Problems" (Prof. Petra, UC Merced) **Fall 2015**

- 11/17/2015: Numerical solution of the advection-diffusion source inverse problem using conjugate gradient method.

"Computational & Variational Inverse Problems" (Prof. Ghattas) **Fall 2015**

- 10/14/2015: Introduction to the FEniCS library for finite element solution of boundary value problems posed in weak form
- 10/28/2015: Numerical solution of inverse problems governed by PDEs using steepest descent
- 11/09/2015: Numerical solution of the Poisson log conductivity inversion problem using the inexact Newton-conjugate gradient method
- 11/16/2015: Numerical study of the spectral properties of the Hessian operator for an advection-diffusion source inverse problem

Emory University, Atlanta, GA

Instructor for undergraduate courses in Calculus I and II

Calculus II (Teaching mentor: Prof. Gould) **Spring 2012**
Calculus I (Teaching mentor: Prof. Garibaldi) **Fall 2011**
Calculus II (Teaching mentor: Prof. Batterson) **Spring 2011**

Teaching Assistant for undergraduate courses in Life Science Calculus and Linear Algebra

Linear Algebra (Lab instructor for Prof. Venapally) **Fall 2012**
Life Science Calculus I (Lab instructor for Prof. Duffus) **Fall 2010**
Life Science Calculus II (Lab instructor for Prof. Duffus) **Spring 2010**
Life Science Calculus I (Lab instructor for Prof. Duffus) **Fall 2009**
Life Science Calculus II (Grader for Prof. Duffus) **Spring 2009**
Life Science Calculus I (Grader for Prof. Duffus) **Fall 2008**
Life Science Calculus II (Grader for Prof. Duffus) **Spring 2008**

Mentoring Experience

Washington University, St. Louis, MO **2018–**

Ph.D. students:

2020 – Present: Luke Lozenski: Scalable methods for the solution of large scale inverse problem governed by partial differential equations with non-smooth regularization.

Mentored PhD students (adviser: A. Anastasio, UIUC):

2018 – Present: Fu Li: Advanced image reconstruction algorithm for 3D accurate and high-resolution breast ultrasound tomography.

2019 – Present: Joseph Kuo: Advancing photoacoustic tomography neuroimaging through model-based image reconstruction and learning.

Ph.D. student rotation projects:

Spring 2019 Tao Ge, *Proximal Newton Methods for Inverse Problems with Non-Smooth Regularization Term*, ESE Department

Fall 2018 Fu Li, *Travel time ultrasound tomography*, Ph.D. in Imaging Science

Fall 2018 Yu Sun, *Automatic time-of-flight pickers for medical ultrasound tomography*, Ph.D. in Imaging Science

Master students' mentored research:

Summer 2020 Ricardo Qiu, *Learning adversarial regularizers for the solution of inverse problems*, CSE Department

Spring 2020 Argho Dattas (Research fellowship), *Learning adversarial regularizers for the solution of inverse problems*, ESE Department

Spring 2020 Jieqiong Xiao (Research fellowship), *ADLA: Automatic differentiation and local assembly of exotic finite element variational forms in MFEM*, CSE Department

Undergraduate students' mentored research:

Summer 2019 Luke Lozenski, Systems Science and Engineering, *Learning forward modeling error in Photoacoustic tomography reconstruction*, Independent study

Spring 2019 Spring Argho Datta, Biomedical Engineering, *Proximal Newton Methods for Medical Imaging*, Independent study

University of Texas at Austin, Austin, TX **2015 –**

Mentored PhD students (adviser: O. Ghattas):
Tom O'Leary-Roseberry (2015 – 2018), dissertation topic: inversion for coupled ice-ocean interaction.
Joshua Chen (2016 – 2018), dissertation topic: Bayesian inference of material properties of cardiac tissue from experimental data.

Master students co-supervised (supervisor: O. Ghattas):
Di Liu (CSEM), *hIPPYLearn: An inexact Stochastic Newton-CG method for training neural networks*, 2017.
Ge Gao (CSEM), *hIPPYLearn: An inexact Newton-CG method for training neural networks with analysis of the Hessian*, 2017.

Undegraduate students co-mentored (mentor: O. Ghattas):
Bassel Saleh (Turing Scholars Honors thesis), *Scientific Machine Learning: A Neural Network-Based Estimator for Forward Uncertainty Quantification*, 2018.

Bassel Saleh (Moncrief Undergraduate Summer Internship), *Neural Networks as Surrogate Models for Forward and Inverse Problems*, 2016.

Informal mentoring:
Trained several graduate students in using the hIPPYlib software to solve inverse problem: A. Alghamdi and B. Crestel (ICES, adviser O. Ghattas), S. Wahal (ICES, adviser G. Biros), and K. McCormack (Jackson School of Geosciences, adviser M. Hesse).
Provided a detailed introduction to the finite element method and the FEniCS software to Samuel Estes (Ph.D student, adviser C. Dawson).

Lawrence Livermore National Laboratory (LLNL), Livermore, CA **2013 – 2015**
PhD students intern supervised (mentor: P. Vassilevski):

M. Christensen (Technical University of Denmark, summers 2013 and 2014): mixed finite element methods and numerical upscaling with application to subsurface flow and petroleum engineering.
S. Ladenheim (Temple University, summer 2013): generation of Gaussian random field by solving stochastic PDEs
D. Emerson (Tufts University, summer 2013): nonlinear multilevel methods
C. S. Lee (Texas A& M, summer 2014): spectral upscaling method for mixed formulation of Darcy equation.

Thesis and Qualifying committees

Ph.D. thesis committee member:

2019 Jingwei Lu, Electrical & Systems Engineering, *Multi-dimensional extension of the alternating minimization algorithm in x-ray computed tomography*; Adviser: Dr. O' Sullivan

Ph.D. thesis proposal committee member:

2020 Uri Goldsztejn, Biomedical Engineering, *Uterine electrophysiology: mathematical modeling, signal processing, and machine learning*; Adviser: Dr. Nehorai

2019 Eghbal Amidi, Biomedical Engineering, *Photoacoustic imaging, feature extraction and quantitative evaluation of in-vivo ovaries and ex-vivo colon samples*; Adviser: Dr. Zhu

Qualifying exam committee member

2020 Tingting Wu, Imaging Sciences, *A computational efficient bound sheds light on point spread function engineering for measuring the orientation of single molecules*; Adviser: Dr. Lew

2020 Zhi Wang, Electrical & Systems Engineering, *Silicon Nitride Waveguide for Chip Based Space-division multiplexing optical coherence tomography*

2019 Soumyendu Ghosh, Electrical & Systems Engineering, *Automatic Quality Assessment of Brain CT Images using Deep Learning*

2019 Jiaming Liu, Electrical & Systems Engineering, *RARE: Image Reconstruction using Deep Priors Learned without Ground Truth*, Adviser: U. Kamilov

Master thesis examination committee member:

2019 Shiqi Xu, Electrical & Systems Engineering, *Regularized Fourier Ptychographic Microscopy*; Adviser: Dr. Kamilov

2019 Weiran Wang, Electrical & Systems Engineering, *Three-dimensional point spread function engineering for high axial localization precision*; Adviser: Dr. Lew

Publications

Peer-Reviewed Journal Articles

O. Babaniyi, R. Nicholson, U. Villa, and N. Petra. "Inferring the basal sliding coefficient field for the Stokes ice sheet model under rheological uncertainty". *The Cryosphere*, 15(4):1731–1750, 2021.

D. Faghihi, J. Tan, U. Villa, N. Shamsaei, S. Shao, and H. Zbib. "A Predictive Discrete-Continuum Multiscale Model of Plasticity With Quantified Uncertainty". *International Journal of Plasticity*, 138:102935, 2021.

H. R. Fairbanks, U. Villa, and P. S. Vassilevski. "Multilevel Hierarchical Decomposition of Finite Element White Noise with Application to Multilevel Markov Chain Monte Carlo". *arXiv e-prints*, 2021.

U. Villa, N. Petra, and O. Ghattas. "hIPPYlib: An Extensible Software Framework for Large-Scale Inverse Problems Governed by PDEs; Part I: Deterministic Inversion and Linearized Bayesian Inference". *ACM Trans. Math. Softw.*, 47(2), April 2021.

P. Chen, U. Villa, and O. Ghattas. "Taylor approximation and variance reduction for PDE-constrained optimal control under uncertainty". *Journal of Computational Physics*, 385:163–186, 2019.

A. Jáuregui, D. Salvo, A. García-Olvera, U. Villa, M. M. Téllez-Rojo, L. M. Schnaas, K. Svensson, E. Oken, R. O. Wright, A. A. Baccarelli, and A. Cantoral. "Physical activity, sedentary time and cardiometabolic health indicators among Mexican children". *Clinical Obesity*, page e12346, 2019.

B. Kramer, A. N. Marques, B. Peherstorfer, U. Villa, and K. Willcox. "Multifidelity probability estimation via fusion of estimators". *Journal of Computational Physics*, 392:385–402, 2019.

M. Christensen, P. S. Vassilevski, and U. Villa. "Nonlinear Multigrid solvers exploiting AMGe coarse spaces with approximation properties". *Journal of Computational and Applied Mathematics*, 340:691 – 708, 2018.

S. Osborn, P. Zulian, T. Benson, U. Villa, R. Krause, and P. Vassilevski. "Scalable hierarchical PDE sampler for generating spatially correlated random fields using non-matching meshes". *Numerical Linear Algebra with Applications*, 25(3):e2146, 2018.

U. Villa, N. Petra, and O. Ghattas. "hIPPYlib: an Extensible Software Framework for Large-scale Deterministic and Bayesian Inverse Problems". *Journal of Open Source Software*, 3(30):940, 2018.

N. Alger, U. Villa, T. Bui-Thanh, and O. Ghattas. "A data scalable augmented Lagrangian KKT preconditioner for large scale inverse problems". *SIAM Journal on Scientific Computing*, 39(5):A2365–A2393, 2017.

P. Chen, U. Villa, and O. Ghattas. "Hessian-based adaptive sparse quadrature for infinite-dimensional Bayesian inverse problems". *Computer Methods in Applied Mechanics and Engineering*, 327:147–172, 2017.

M. Christensen, U. Villa, A. Engsig-Karup, and P. S. Vassilevski. "Numerical upscaling for incompressible flow in reservoir simulation: an element-based algebraic multigrid (AMGe) approach". *SIAM Journal on Scientific Computing*, 39(1):B102–B137, 2017.

S. Guzzetti, T. Passerini, J. Slawinski, U. Villa, A. Veneziani, and V. Sunderam. "Platform and algorithm effects on computational fluid dynamics applications in life sciences". *Future Generation Computer Systems*, 67:382 – 396, 2017.

S. Osborn, P. S. Vassilevski, and U. Villa. "A Multilevel Hierarchical Sampling Technique for Spatially Correlated Random Fields". *SIAM Journal on Scientific Computing*, 39(5):S543–S562, 2017.

D. Kalchev, C. S. Lee, U. Villa, Y. Efendiev, and P. S. Vassilevski. "Upscaling of mixed finite element discretization problems by the spectral AMGe method". *SIAM Journal on Scientific Computing*, 38(5):A2912–A2933, 2016.

D. Salvo, C. Torres, U. Villa, J. A. Rivera, O. L. Sarmiento, R. S. Reis, and M. Pratt. "Accelerometer-based physical activity levels among Mexican adults and their relation with sociodemographic characteristics and BMI: a cross-sectional study". *Int. J. Behavioral Nutrition and Physical Activity*, 12(79):1–11, 2015.

P. S. Vassilevski and U. Villa. "A mixed formulation for the Brinkman problem". *SIAM Journal on Numerical Analysis*, 52(1):258–281, 2014.

K. W. Desmond, U. Villa, M. Newey, and W. Losert. "Characterizing the rheology of fluidized granular matter". *Physical Review E*, 88(3):032202, 2013.

T. Passerini, A. Quaini, U. Villa, A. Veneziani, and S. Canic. "Validation of an open source framework for the simulation of blood flow in rigid and deformable vessels". *Int. J. Numerical Methods in Biomedical Engineering*, 29(11):1192–1213, 2013.

P. S. Vassilevski and U. Villa. "A block-diagonal algebraic multigrid preconditioner for the Brinkman problem". *SIAM Journal on Scientific Computing*, 35(5):S3–S17, 2013.

A. Veneziani and U. Villa. "ALADINS: An ALgebraic splitting time ADaptive solver for the Incompressible Navier–Stokes equations". *Journal of Computational Physics*, 238:359–375, 2013.

Conference Proceedings

Joseph Kuo, Jason Granstedt, Umberto Villa, and Mark A. Anastasio. "Learning a projection operator onto the null space of a linear imaging operator". In Hilde Bosmans, Wei Zhao, and Lifeng Yu, editors, *Medical Imaging 2021: Physics of Medical Imaging*, volume 11595, pages 1019 – 1025. International Society for Optics and Photonics, SPIE, 2021.

Fu Li, Umberto Villa, Seonyeong Park, Shenghua He, and Mark A. Anastasio. "A framework for ultrasound computed tomography virtual imaging trials that employs anatomically realistic numerical breast phantoms". In Brett C. Byram and Nicole V. Ruiter, editors, *Medical Imaging 2021: Ultrasonic Imaging and Tomography*, volume 11602. International Society for Optics and Photonics, SPIE, 2021.

Seonyeong Park, Umberto Villa, Frank J. Brooks, Richard Su, Alexander A. Oraevsky, and Mark A. Anastasio. "Three-dimensional quantitative functional optoacoustic tomography to estimate vascular blood oxygenation of the breast". In Alexander A. Oraevsky and Lihong V. Wang, editors, *Photons*

Plus Ultrasound: Imaging and Sensing 2021, volume 11642. International Society for Optics and Photonics, SPIE, 2021.

Chao Wang, Umberto Villa, Weylan Thompson, Seonyeong Park, Sergey A. Ermilov, and Mark A. Anastasio. "Dynamic reconstruction of three-dimensional photoacoustic tomography from few projections". In Alexander A. Oraevsky and Lihong V. Wang, editors, *Photons Plus Ultrasound: Imaging and Sensing 2021*, volume 11642. International Society for Optics and Photonics, SPIE, 2021.

T. Ge, U. Villa, U. S. Kamilov, and J. A. O'Sullivan. "Proximal Newton Methods for X-Ray Imaging with Non-Smooth Regularization". In *Proc Electronic Imaging*. Society for Imaging Science and Technology, 2020.

P. Chen, U. Villa, and O. Ghattas. "Taylor approximation for PDE-constrained optimization under uncertainty: Application to turbulent jet flow". In *Proceedings in Applied Mathematics and Mechanics - 89th GAMM Annual Meeting*, volume 18, page e201800466. 2018.

M. Neumüller, P. S. Vassilevski, and U. Villa. *Space-time constrained First Order Systems Least Squares (CFOSLS) with AMGe upscaling*, pages 253–260. Springer, 2017.

M. Christensen, U. Villa, and P. S. Vassilevski. "Multilevel techniques lead to accurate numerical upscaling and scalable robust solvers for reservoir simulation". In *SPE Reservoir Simulation Symposium*. Society of Petroleum Engineers, 2015.

T. Passerini, J. Slawinski, U. Villa, and V. Sunderam. "Experiences with Cost and Utility Tradeoffs on IaaS Clouds, Grids, and On-Premise Resources". In *Proc. IEEE Intl. Conference on Cloud Engineering (IC2E) - Cloud Analytics Workshop*, pages 391–396. IEEE, 2014.

J. Slawinski, U. Villa, T. Passerini, A. Veneziani, and V. Sunderam. "Issues in Communication Heterogeneity for Message-Passing Concurrent Computing". In *27th IEEE Intl. Parallel and Distributed Processing Symposium Workshops & PhD Forum (IPDPSW)*, pages 93–102. IEEE, 2013.

J. Slawinski, U. Villa, T. Passerini, A. Veneziani, and V. Sunderam. "Experiences with Target-Platform Heterogeneity in Clouds, Grids, and On-Premises Resources". In *26th IEEE Intl. Parallel and Distributed Processing Symposium Workshops & PhD Forum (IPDPSW)*, pages 41–52. IEEE, 2012.

Submitted Manuscripts

A Alghamdi, M. Hesse, J. Chen, U. Villa, and O. Ghattas. "Bayesian Poroelastic Aquifer Characterization from InSAR Surface Deformation Data Part II: Quantifying the Uncertainty". *Water Resources Research*, *submitted*, 2021.

T. O'Leary-Roseberry, U. Villa, P. Chen, and O. Ghattas. "Derivative-Informed Projected Neural Networks for High-Dimensional Parametric Maps Governed by PDEs". *arXiv preprint*, 2021.

Theses

Doctoral Dissertation: *Scalable Efficient Methods for Incompressible Fluid-dynamics in Engineering Problems*. Advisor: A. Veneziani.

Alta Scuola Politecnica diploma: *Environment & energy - Hydrogen: opportunities and utilization*. Advisors: F. Profumo, E. Paolucci, A. Tenconi. External Institutions: Centro Estero Camere di Commercio Piemontesi, STEP Ricerche S.r.l.

Master Dissertation: *Finite Element Analysis of the Brake Pad System and Multibody Modeling of Motor Vehicles in Braking-Phase*. Advisor: A. Veneziani, L. Trainelli, A. Vigliani. External Institutions:"Simulations and Computing" division of Brembo Sps.

Bachelor Dissertation: *Mathematical modeling and numerical simulation of hemodynamics problems in one dimension*. Advisor: A. Veneziani.

Conference presentations

Award winning presentations

A Block-Diagonal Algebraic Multigrid Preconditioner for the Brinkman Problem, 12th Copper Mountain Meeting on Iterative Methods, March 25-30, 2012, Copper Mountain, Colorado, US (student paper competition)

Invited oral presentations in mimisymposia

Curvature Enhanced MCMC Algorithms for Bayesian Inverse Problems Governed by PDEs, SIAM Conference on Computational Science and Engineering, March 1-5, 2021, held virtually

Proximal Newton Method for Inverse Problems with Non-smooth Regularization Term, SIAM Conference on Imaging Science, July 6-9, 2020, Toronto, Canada

Scalable optimal experimental design for large scale non-linear Bayesian inverse problems, Applied Inverse Problems, July 8-12, 2019, Grenoble, France

Scalable Methods for Bayesian Optimal Experimental Design Using Laplace Approximation, SIAM Conference on Computational Science and Engineering, Feb 25- March 1, 2019, Spokane, WA, US

Maximize the Expected Information Gain in Bayesian Experimental Design Problems: a Fast Optimization Algorithm Based on Laplace Approximation and Randomized Eigensolvers, SIAM Conference on Uncertainty Quantification, April 16-19, 2018, Garden Grove, CA, US

Taylor Approximation for PDE-Constrained Optimal Control Problems Under High-Dimensional Uncertainty: Application to a Turbulence Model, SIAM Conference on Control and its Applications, July 10-12, 2017, Pittsburgh, PA, US

Derivative-informed MCMC for Bayesian Calibration of Stochastic PDE Models, SIAM Annual Meeting, July 10-14, 2017, Pittsburgh, PA, US

Hessian-based Sampling Techniques for Bayesian Inverse Problems with Stochastic PDE Forward Model, Applied Inverse Problems, May 29-Jun 2, 2017, Hangzhou, China

Bayesian Calibration of Inadequate Stochastic PDE Models, SIAM Conference on Computational Science and Engineering, Feb 27-March 3, 2017, Atlanta, GA, US

Bayesian Inverse Problems Governed by Stochastic PDE Models, Joint Mathematics Meetings, January 4-7, 2017, Atlanta, GA, US

An Analytical Technique for Forward and Inverse Propagation of Uncertainty, SIAM Conference on Uncertainty Quantification, April 5-8, 2016, Lausanne, Switzerland

Highly Scalable Hierarchical Sampling Algorithms for Gaussian Random Fields, SIAM Conference on Computational Science and Engineering, March 14-18, 2015, Salt Lake City, UT, US

Robust Numerical Methods for the Brinkman Problem, 9th International Conference on Large-Scale Scientific Computations, June 3-7, 2013, Sozopol, Bulgaria (with travel support from symposium organizers)

PALADINS: Scalable Time-adaptive Algebraic Splitting and Preconditioners for the Navier-Stokes Equations, SIAM Conference on Computational Science and Engineering, Feb 25-March 1, 2013, Boston, MA, US

ALADINS: an ALgebraic ADaptive Incompressible Navier-Stokes solver, XVIII International Conference on Computational Methods in Water Resources, June 21-24, 2010, Barcelona, Spain (student volunteer with partial travel support)

Oral presentations

Bayesian Inference of Fault Properties in Two-phase Porous Media Flow, 56^th Annual Technical Meeting of Society of Engineering Science, October 13-15, 2019, St. Louis, MO, US

hIPPYlib: An Extensible Software Framework for Large-Scale Bayesian Inverse Problems with Quantified Uncertainties, FEniCS Conference, June 12-14, 2019, Washington, D.C., US

hIPPYlib: An Extensible Software Framework for Large-Scale Deterministic and Linearized Bayesian Inverse Problems, Texas Applied Mathematics and Engineering Symposium, Sept. 21–23, 2017, Austin, TX, US

AMG Solvers for Upscaled Mixed Finite Element Discretizations, 13th Copper Mountain Conference on Iterative Methods, Apr 6 - 11, 2014, Copper Mountain, CO, US

Multilevel Monte Carlo Simulations with Algebraically Constructed Coarse Spaces, SIAM Conference on Uncertainty Quantification, March 31 - Apr 3, 2014, Savannah, GA, US

Block AMG Preconditioners For Mixed Finite Element Discretization of Porous Media Flow Problems, 16th Copper Mountain Conference on Multigrid Methods, March 17-22, 2013, Copper Mountain, CO, US

PALADINS: a Scalable Solver for the Navier-Stokes Equations, SIAM Conference on Parallel Processing for Scientific Computing, Feb 15-17, 2012, Savannah, GA, US

PALADINS: A Parallel Algebraic Adaptive Navier-Stokes Solver, SIAM Conference on Computational Science and Engineering, Feb 28-March 4, 2011, Reno, NV, US

Poster presentations

Integrating Data with Complex Predictive Models under Uncertainty: An Extensible Software Framework for Large-Scale Bayesian Inversion, NSF CSSI PI Meeting, 2020, Seattle, Wa, US

Systematic Integration of Data with Models under Uncertainty, 21st Century Imaging Sciences Pathway Annual Retreat, June 7^{th}, 2019, St. Louis, MO, US

Integrating Data with Complex Predictive Models under Uncertainty: An Extensible Software Framework for Large-Scale Bayesian Inversion, NSF SI2 PI Meeting, 2017, Arlington, VA, US

Hard problems are fine to coarsen, Computation Postdoc Poster Symposium, March 24^{th}, 2014, Livermore, CA, US

Upscaling Techniques for the Brinkman Problem, 2013 DOE Applied Mathematics Program meeting, August 6-8, 2013, Albuquerque, NM, US

Towards Scalable Solvers for the Brinkman Problem, Lawrence Livermore Student Poster Symposium, August 8^{th}, 2012, Livermore, CA, US

Robust numerical methods for the Brinkman problem, Lawrence Livermore Student Poster Symposium, August 10^{th}, 2011, Livermore, CA, US

ALgebraic time ADaptive splitting schemes for the Incompressible Navier-Stokes equations, 2011 Georgia Scientific Computing Symposium, Feb. 12^{th}, 2011, Atlanta, GA, US

Multiphysics Multimodel Domain Decomposition: An Application to Conjugate Heat Transfer, 2010 Georgia Scientific Computing Symposium, Feb. 20^{th}, 2010, Atlanta, GA, US

Seminars

Quantitative Photoacoustic Tomography: Inversion Algorithms & Challenges, Georgia Tech, Atlanta, GA, June 25^{th}-26^{th}, 2019, *1st Annual Photoacoustic & Florescence Tomography Workshop*

Learning from data through the lens of mathematical models: Bayesian Inverse Problems and Uncertainty Quantification, Department of Mathematics, Emory University, Atlanta, GA, June 24^{th}, 2019. Host *A. Veneziani*

Learning from data through the lens of mathematical models: A gentle introduction to Bayesian Inverse Problems, Mathematics Department, Washington University, St. Louis, MO, January 28^{th}, 2019. Host *J. McCarthy*

Large Scale Inverse Problems and Uncertainty Quantification: Computational Tools and Imaging Applications, Electrical & Systems Engineering, Washington University, St. Louis, MO, January 24^{th}, 2019. Host *J. O'Sullivan*

Numerical Upscaling and Multilevel Monte Carlo, Stanford University, Palo Alto, CA, November 12^{th}, 2014, *Algorithms and Architectures Initiative Annual Meeting.*

Multilevel Monte Carlo Simulations with Algebraically Constructed Coarse Spaces, Emory University, Atlanta, GA, March 28^{th}, 2014. Host *A. Veneziani*

Towards Scalable Solvers for the Brinkman Problem, Stanford University, Palo Alto, CA, March 4^{th}, 2014. Host *H. Techelepi*

Numerical Upscaling and Algebraic Multigrid for Mixed Finite Element discretizations, Lawrence Berkeley National Laboratory, Berkeley, CA, February 11^{th}, 2014. Host *X. S. Li*

Numerical Upscaling and Algebraic Multigrid for Mixed Finite Element discretizations, Tuft University, Boston, MA, December 6^{th}, 2013. Host *J. Adler*

An Optimal Control Approach for Multiphysics Multimodel Domain Decomposition, Stanford University, Palo Alto, CA, November 7^{th}, 2013. Host *M. Saunders*

Towards Scalable Solvers for the Brinkman Problem, Kennesaw State University, Kennesaw, GA, October 5^{th}, 2013. Host *Y. Babenko*

Schools, Workshops, and Think-tanks

Big Data Inverse Problems, April 18-23, 2021, Banff International Research Station, Banff, Canada (by invitation only)

Computational Uncertainty Quantification: Mathematical Foundations, Methodology & Data, May 4-8, 2020, Erwin Schroedinger Institute for Mathematics and Physics (ESI), University of Vienna, Vienna, Austria (by invitation only, virtual)

IdeaLab 2015: Inverse Problems and Uncertainty Quantification, July 6-10, 2015, Institute for Com-

putational and Experimental Research in Mathematics (ICERM), Brown University, Providence, Rhode Island, Us (with travel support from organizers)

Algebraic Multigrid Summit, October 15-18, 2014, Boulder, Colorado, US (by invitation only)

Algebraic Multigrid Summit, September 3-8, 2013, Lake City, Colorado, US (by invitation only)

Finite Element Exterior Calculus Summer School, June 11-15, 2012, Institute for Computational and Experimental Research in Mathematics (ICERM), Brown University, Providence, Rhode Island, US (with travel support from organizers)

Adaptive Finite Elements and Domain Decomposition Methods Workshop, June 17-19, 2010, Milan State University, Milan, Italy

Parallel Numerical Simulation School (Athens Program), March 18-23, 2007, Technische Universität München, Munich, Germany

Crash Analysis and Car Dynamics School (Athens Program), November 12-17, 2006, Ecole Nationale des Ponts et Chaussees, Paris, France

Open source scientific software contributions

- Lead developer of hIPPYlib - **I**nverse **P**roblems **Py**thon **lib**rary (`https://hippylib.github.io`)
- Lead developer of Elag, ParElag (element agglomeration multigrid solvers and upscaling tools, `http://github.com/LLNL/parelag`)
- Lead developer of ElagMC, ParElagMC (Multilevel Monte Carlo software based on Elag/ParElag, `https://github.com/LLNL/parelagmc`)
- Contributor to the finite element library MFEM (`http://mfem.org`)
- Developer of the finite element library LifeV (`www.lifev.org`)

Service to scientific community

Editorial work

Serving as *editorial board member* of *Numerical Linear Algebra with Applications* since 2018.
Serving as a *reviewer* for the following journals: *SIAM Journal for Uncertainty Quantification*, *SIAM Journal on Scientific Computing* (SIAM); *Numerical Linear Algebra with Applications*, *Numerical Methods in Engineering* (Wiley); *Computational Geosciences*, *Journal of Scientific Computing*, *Numerical Algorithms*, *Advances in Computational Mathematics*, *Numerische Mathematik* (Springer); *Transactions on Medical Imaging* (IEEE), *Photoacoustics*, *Journal of Mathematical Analysis and Applications* (Elsevier), *Ultrasonic Imaging* (SAGE)

Grant reviews

Served in 1 NSF grant review panel (Office of Advanced Cyberinfrastructure)

Education and training

Organize and teach the *2018 Gene Golub SIAM Summer School* on *Inverse Problems: Systematic Integration of Data with Models under Uncertainty*, in collaboration with O. Ghattas, Y. Marzouk, M. Parno, N. Petra, and G. Stadler

Minisymposia organization

N. Petra, M. Parno, U. Villa, *Computational tools for inverse problems governed by partial differential equations and uncertainty quantification*, SIAM Conference on Uncertainty Quantification, March 24-27, 2020, Munich, Germany
U. Villa, O. Ghattas, *Optimal Experimental Design for Bayesian Inverse Problems*, SIAM Conference on Computational Science and Engineering, Feb 25-March 1, 2019, Spokane, WA, US
U. Villa, T. Oliver, N. Petra, O. Ghattas, R. Moser, *Characterizing model inadequacy in Bayesian inference*, SIAM Conference on Uncertainty Quantification, April 16-19, 2018, Garden Grove, CA, US
T. Bui-Thanh, O. Ghattas, V. Rao, U. Villa, *Efficient Algorithms for Bayesian Inverse Problems Governed by PDE Forward Problems*, SIAM Conference on Computational Science and Engineering, Feb 27-March 3, 2017, Atlanta, GA, US

Departmental & Institutional service

Washington University, St. Louis, MO

- Serve as member of the Ph.D. in Imaging Science curriculum committee (2020-2021)
- Serve in examination committees: 1 Ph.D. thesis, 2 Ph.D. thesis proposal, 4 qualifying exams, 2 Master theses

- Meet and interview candidates applying for faculty positions
- Supervise undergraduate and master research
- Participate in recruit activities for prospective undergraduate and master students, including
    - The reception for prospective Ph.D. students in the McKelvey School of Engineering (Spring 2020)
    - The Electrical & Systems Engineering Research Lab Poster Session aimed at introducing upper-undergraduate and master student to the research carried on in the department (Fall 2019)
    - The Pre-Engineering Institute week aiming at recruiting high-school students from around the country and the world (Summer 2010)
    - The reception for admitted students in the Ph.D. in Imaging Science and Computational Data Science (Spring 2019)

Lawrence Livermore National Laboratory, Livermore, CA
- Meet and interview candidates applying for postdoctoral and staff positions

PROFESSIONAL AFFILIATIONS

SIAM member since 2009.
IEEE member since 2019.