Umberto Emanuele Villa

CONTACT INFORMATION

Washington University in St. Louis
Electrical & Systems Engineering
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St. Louis, MO, 63130

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I define myself as a mathematical engineer and computational scientist. My work focuses on advancing our understanding of physical and biological phenomena, improving the design of engineering systems, and supporting informed decision-making under uncertainty by use of mathematical/statistical modeling and high-performance computing. An important component of my work is the systematic integration of mathematical models and data (e.g., experimental measures and images) using the Bayesian framework. Throughout my career, I have led the development of novel formulations and algorithms for the solution of both forward and inverse problems. I have achieved this by establishing a close working collaboration with some of the leading research experts in the fields of geophysics, biomedical imaging, computational sciences, applied mathematics, and engineering.

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

Seno Medical Best Paper Award, Photons Plus Ultrasound: Imaging and Sensing 2022, SPIE Photonics West BIOS, San Francisco, CA, US (co-author) **2022**

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**

Grants and Contracts

Awarded

T. Kim (PI); L. Henke, G. Hugo, C. Park, M. Schmidt,**U. Villa**, H. Yi (**Co-Is**), *MRI augmented X-ray imaging-guided adaptive radiotherapy for pancreatic cancer (MAX-guided ART)*, Siteman Investment Program (Pre-R01 Award)
07/01/2021–06/30/2023 **$200,000**

M. Anastasio and N. Duric (PIs); **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 awarded to date $1,604,478; expected **$2.2M**
WUSTL subaward amount $250,761

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 **$59,999**

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**
WUSTL subaward amount $50,000
Note: A collaborative research project (separate awards) with N. Petra (UC-Merced), 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 (SIAM)
Note: training grant for organizing a 2-week summer school on inverse problems in Breckenridge, CO
June 16—30, 2018 **$109,200**

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, 2019–2020, 100,000 CPU hours (estimated value of awarded resources $8,445).

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 fast model-based image reconstruction methods for emerging imaging modalities, including ultrasound computed tomography and multispectral photoacoustic tomography.
Design of high-fidelity computational frameworks for virtual imaging trails.

Development of numerical observers for task-based image quality.
Predictive computational modeling for material science and precision medicine.

- *Advanced image reconstruction for accurate and high-resolution breast ultrasound tomography*
  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.
  Funding: National Institute of Health, National Institute of Biomedical Imaging and Bioengineering (NIBIB), R01EB028652. M. Anastasio (PI)
  Role: **Co-Investigator/Subaward PI**
- *A computational framework enabling quantitative 3D optoacoustic imaging of vasculature and oxygen saturation within the human breast*
  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.
  Collaboration with M. Anastasio and A. Oraevsky (Tomowave Inc)
- *Dynamic spectral photoacoustic imaging of murine models*
  This project aims at developing learning-enhanced image reconstruction to enable quantitative dynamic PACT imaging from a reduced number of tomographic views.
  Collaboration with M. Anastasio and S. Ermilov (Photosound Inc)
- *Safe, rapid & functional pediatric brain imaging using photoacoustic computed tomography*
  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).
  Funding: NIH, National Institute of Neurological Disorders and Stroke (NINDS), R01NS102213. L. Wang, M. Anastasio (PIs)
  Role: **Other personnel**
- *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.
  Funding: NSF, Office of Advanced Cyberinfrastructure, ACI-1550593. O. Ghattas (PI)
  Role: **Co-PI**
- *Predictive modeling for computational oncology* 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.
  Collaboration with D. Faghihi (The University at Buffalo)
- *Predictive modeling for material science* The overarching goal of this project is to develop, calibrate, and validate multiscale computational models to characterize microstructure properties of aerogel materials and predict their macroscopic thermal and mechanical behavior.
  Collaboration with D. Faghihi (The University at Buffalo)

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*
  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.
  Funding: NSF, Office of Advanced Cyberinfrastructure, ACI-1550593. O. Ghattas (PI)

Role: **Co-PI**

- *Bayesian Optimal Experimental Design for Inverse Scattering*
  The goal of this study is to develop a rigorous Bayesian framework to design source/receiver configuration to maximize identifiability.
  Funding: Air Force Office of Scientific Research, Computational Mathematics program, FA9550-17-1-0190. O. Ghattas (PI), G. Biros and Y. Marzouk (Co-PIs)
  Role: Research scientist
- *Large-scale Inverse Problems and Uncertainty Quantification for Reservoir Modeling*
  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.
  Funding: Joint ExxonMobil-UT Energy Institute Project, UTA17-000408 (EM10480.14). O. Ghattas (PI), G. Biros, T. Bui-Thanh, C. Dawson (Co-PIs)
  Role: Research scientist
- *Inference, Simulation, and Optimization of Complex Systems Under Uncertainty: Theory, Algorithms, and Applications to Turbulent Combustion*
  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.
  Funding: 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)
  Role: Research scientist

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)*
  This project developed large scale linear solvers and preconditioners exploiting multilevel techniques and hierarchical matrices factorizations.
  Funding: DOE Office of Advanced Scientific Computing Research. X.-S. Li (lead PI), P. Vassilevski (LLNL PI)
  Role: Postdoctoral researcher
- *Scalable Multilevel UQ Concepts for Extreme-Scale Multiscale Problems*
  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.
  Funding: DOE Office of Advanced Scientific Computing Research. Y. Efendiev (lead PI), P. Vassilevski (LLNL PI)
  Role: Postdoctoral researcher
- *Adaptive Dimension Reduction via Coarsening and Multilevel Solvers*
  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.
  Funding: DOE Office of Advanced Scientific Computing Research. P. Vassilevski (PI)
  Role: Graduate research assistant

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): 2 lectures	**Spring 2020**
Optimization (Prof. Kamilov): 1 lecture	**Spring 2019**

University of Texas, Austin, TX

Instructor of the 2018 Gene Golub SIAM Summer School
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): 3 lectures	**Fall 2016**
Computational & Variational Inverse Problems (Prof. Ghattas): 4 lectures	**Fall 2015**
Comput. & Variational Inverse Problems (Prof. Petra, UC Merced): 1 lecture	**Fall 2015**

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[1] **2018–**

Ph.D. students:

Luke Lozenski (ESE, 2020 –): Integration of model-based and learned image reconstruction algorithms for quantitive dynamic multispectral photoacoustic imaging of small animal models

[1] ESE = Electrical & System Engineering; CSE = Computer Science Engineering; BME = Biomedical Engineering; IS = Imaging Science Ph.D. program, BIOE=Biomedical Engineering (UIUC), ECE=Electrical & Computer Engineering (UIUC)

M.S. students:

Ricardo Qiu (CSE, 2021): *Data-driven approaches to solve inverse problems*

Co-mentored PhD students (adviser: A. Anastasio, UIUC):

Fu Li (BIOE, 2018 –): Advanced image reconstruction algorithm for 3D accurate and high-resolution breast ultrasound tomography

Joseph Kuo (ECE, 2019 –): Advancing photoacoustic tomography neuroimaging through model-based image reconstruction and learning

Refik Cam (ECE, 2020 –): Small animal photoacoustic imaging

PhD students' rotation projects:

Luke Lozenski (ESE, Fall 2020): *Scalable methods for the solution of large scale inverse problem governed by partial differential equations with non-smooth regularization*

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

Fu Li (IS, Fall 2018): *Travel time ultrasound tomography*

Yu Sun (IS, Fall 2018): *Automatic time-of-flight pickers for medical ultrasound tomography*

Master students' mentored research:

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

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

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

Undergraduate students' mentored research (independent studies):

Luke Lozenski (ESE, Summer 2019): *Learning forward modeling error in Photoacoustic tomography reconstruction*

Argho Datta (BME, Spring 2019): *Proximal Newton Methods for Medical Imaging*

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

Co-mentored PhD students (adviser: O. Ghattas):

Tom O'Leary-Roseberry (2020): *Efficient and dimension independent methods for neural network surrogate construction and training*

Amal Alghamdi (2020): *Bayesian inverse problems for quasi-static poroelasticity with application to ground water aquifer characterization from geodetic data*

Co-supervised Master students (supervisor: O. Ghattas):

Di Liu (CSEM, 2017): *hIPPYLearn: An inexact Stochastic Newton-CG method for training neural networks*

Ge Gao (CSEM, 2017): *hIPPYLearn: An inexact Newton-CG method for training neural networks with analysis of the Hessian*

Co-mentored undegraduate students (mentor: O. Ghattas):

Bassel Saleh (Turing Scholars Honors thesis, 2018): *Scientific Machine Learning: A Neural Network-Based Estimator for Forward Uncertainty Quantification*

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

Lawrence Livermore National Laboratory (LLNL), Livermore, CA **2013 – 2015**

Co-supervised PhD students intern (supervisor: 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

PUBLICATIONS

Peer-Reviewed Journal Articles

Publications with a leading role (first author, last author, equal contributions by all authors)[2]

Fu Li, Umberto Villa, Seonyeong Park, and Mark A Anastasio. "Three-dimensional stochastic numerical breast phantoms for enabling virtual imaging trials of ultrasound computed tomography". *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, 69(1):135–146, 2022.

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.

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". *SIAM Journal on Scientific Computing*, 43(5):S293–S316, 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.

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.

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.

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. 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.

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

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.

Publications with significant contributions as co-author

Joseph Kuo, Jason Granstedt, Umberto Villa, and Mark A. Anastasio. "Computing a Projection Operator onto the Null Space of a Linear Imaging Operator: Tutorial". *Journal of the Optical Society of America A*, in print, 2022.

T. O'Leary-Roseberry, U. Villa, P. Chen, and O. Ghattas. "Derivative-Informed Projected Neural Networks for High-Dimensional Parametric Maps Governed by PDEs". *Computer Methods in Applied Mechanics and Engineering*, 388:114199, 2022.

Simone Puel, Eldar Khattatov, Umberto Villa, Dunyu Liu, Omar Ghattas, and Thorsten W Becker. "A Mixed, Unified Forward/Inverse Framework for Earthquake Problems: Fault Implementation and Coseismic Slip Estimate". *Geophysical Journal International*, in print, 2022.

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*, 57(11):e2021WR029775, 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.

[2] Order of authors does not always reflect level of contributions. Depending on the field, in some publications, authors are ordered alphabetically or by level of seniority (students firsts, postdoc and research scientists next, professors at last).

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.

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.

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.

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

Other publications

Jingye Tan, Pedram Maleki, Lu An, Massimigliano Di Luigi, Umberto Villa, Chi Zhou, Shenqiang Ren, and Danial Faghihi. "A Predictive Multiphase Model of Silica Aerogels for Building Envelope Insulations". *Computational Mechanics*, in print, 2022.

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.

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.

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.

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.

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.

Conference Proceedings

Refik Cam, Umberto Villa, and Mark Anastasio. "A Learned Filtered Backprojection Method for use with Half-Time Circular Radon Transform Data". In *Medical Imaging 2022: Physics of Medical Imaging*, volume accepted. International Society for Optics and Photonics, SPIE, 2022.

Jason Granstedt, Umberto Villa, and Mark Anastasio. "Learned Hotelling Observers for use with Multi-Modal Data". In *Medical Imaging 2022: Image Perception, Observer Performance, and Technology Assessment*, volume accepted. International Society for Optics and Photonics, SPIE, 2022.

Fu Li, Umberto Villa, Neb Duric, and Mark A. Anastasio. "Investigation of an elevationally focused transducer model for three-dimensional full-waveform inversion in ultrasound computed tomography". In *Medical Imaging 2022: Ultrasonic Imaging and Tomography*, volume accepted. International Society for Optics and Photonics, SPIE, 2022.

Luke Lozenski, Mark Anastasio, and Umberto Villa. "Implicit Neural Representation for Dynamic Imaging". In *Medical Imaging 2022: Physics of Medical Imaging*, volume accepted. International Society for Optics and Photonics, SPIE, 2022.

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.

Seonyeong Park, Umberto Villa, Richard Su, Alexander Oraevsky, Frank J. Brooks, and Mark A. Anastasio. "Realistic three-dimensional optoacoustic tomography imaging trials using the VICTRE breast phantom of FDA (Conference Presentation)". In Alexander A. Oraevsky and Lihong V. Wang, editors, *Photons Plus Ultrasound: Imaging and Sensing 2020*, volume 11240. International Society for Optics and Photonics, SPIE, 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

Sayantan Bhadra, Umberto Villa, and Mark Anastasio. "Mining the manifolds of deep generative models for multiple data-consistent solutions of ill-posed tomographic imaging problems". *IEEE Transactions on Medical Imaging*, 2022.

Delyan Z Kalchev, Panayot S Vassilevski, and Umberto Villa. "Parallel Element-based Algebraic Multigrid for H (curl) and H (div) Problems Using the ParELAG Library". *arXiv preprint arXiv:2107.05613*, 2021.

Ki-Tae Kim, Umberto Villa, Matthew Parno, Youssef Marzouk, Omar Ghattas, and Noemi Petra. "hIPPYlib-MUQ: A Bayesian Inference Software Framework for Integration of Data with Complex Predictive Models under Uncertainty". *arXiv preprint arXiv:2112.00713*, 2021.

Luke Lozenski and Umberto Villa. "Consensus ADMM for Inverse Problems Governed by Multiple PDE Models". *arXiv preprint arXiv:2104.13899*, 2021.

Seonyeong Park, Frank Brooks, Umberto Villa, Richard Su, Mark Anastasio, and Alexander Oraevsky. "Normalization of optical fluence distribution for three-dimensional functional optoacoustic tomography of the breast". *Journal of Biomedical Optics*, 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

Scalable Laplace Approximation for Bayesian Optimal Experimental Design, 13$^{\text{th}}$ International Conference on Monte Carlo Methods, August 16-20, 2021, University of Mannheim, Germany (held virtually)

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

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

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

Three-dimensional stochastic numerical breast phantoms for enabling virtual imaging trials of ultrasound and photoacoustic computed tomography, Department of Mechanical and Aerospace Engineering, University at Buffalo, Buffalo, NY, November 4^th, 2021. Host *D. Faghihi*

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 by invitation only

Big Data Inverse Problems, TBD, 2023, Banff International Research Station, Banff, Canada

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

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

Algebraic Multigrid Summit, September 3-8, 2013, Lake City, Colorado, US

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)

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*, *International Journal for 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*, *SoftwareX* (Elsevier), *Optics Letters* (Optica), *Ultrasonic Imaging* (SAGE), Journal of Numerical Mathematics (De Gruyter)

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/conference-session organization

D. Faghihi, K. Maupin, A. Tabarraei, U. Villa, *Data-Enabled Predictive Modeling, Machine Learning, and Uncertainty Quantification in Computational Mechanics*, ASME's International Mechanical Engineering Congress & Exposition, Nov 1-4, 2021, *virtual*

D. Faghihi, K. Maupin, A. Tabarraei, U. Villa, *Data-Enabled Predictive Modeling, Machine Learning, and Uncertainty Quantification in Computational Mechanics*, ASME's International Mechanical Engineering Congress & Exposition, Nov 15-19, 2020, *virtual*

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 6 Ph.D. thesis committees: Austen Curcuru (BME, *current*), Shuying Li (BME, *current*), Tingting Wu (IS, *current*), Uri Goldsztejn (BME, *current*), Eghbal Amidi(BME, 2021), Jingwei Lu (ESE, 2019)[3]
- Serve in 3 M.S. thesis committees: Shangguan Wentao (ESE, 2021), Weiran Wang (ESE, 2019), Shiqi Xu (ESE, 2019)
- Serve in 4 Ph.D. qualifying exam committees: Tingting Wu (IS, 2020), Zhi Wang (IS, 2020), Soumyendu Ghosh (ESE, 2019), Jiaming Liu (ESE, 2019)
- Supervise undergraduate and master research
- Participate in recruit activities for prospective undergraduate and master students
- Meet and interview candidates applying for faculty positions

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.

[3] BME=Biomedical Engineering, IS=Imaging Science Ph.D. ESE=Electrical & Systems Engineering