Nicolas Charon

Assistant Professor, Department of Applied Mathematics
Center of Imaging Sciences, Clark Hall 320A
3400 N. Charles Street
Baltimore MD 21218

Phone: 410-516-7848
Email: charon@cis.jhu.edu

A. Biographical information

Education

- Ph.D in applied mathematics, ENS Cachan, 2013
  - *Title :* Analysis of geometric and functional shapes with extensions of currents. Applications to registration and atlas estimation.
  - *Advisor:* Pr. Alain Trouvé, ENS Cachan.
- M.S in applied mathematics (specialization in computer vision), ENS Cachan 2008.
  - *Thesis title :* Target detection in radar images based on geometric averages of covariance matrices.
  - *Advisor:* Dr. Frederic Barbaresco, Thales Air Systems.
- B.S in Mathematics, ENS Cachan & Université Paris 7, 2007.

Academic and other research positions

- Assistant Professor, The Johns Hopkins University, Department of Applied Mathematics and Statistics, January 2015-present.
- Post-doctoral research fellow, University of Copenhagen, Department of Computer Science, January 2014- December 2014.
- Research assistant at Thales Air Systems (France), April 2008 - August 2008.

Current affiliations

- Department of Applied Mathematics and Statistics (AMS).
- Center of Imaging Sciences (CIS).
- Institute of Computational Medicine (ICM).

B. Research activities

Journal Publications

1. Y. Sukurdeep, M. Bauer and N. Charon. A new variational model for the analysis of shape graphs with partial matching constraints. *To appear in SIAM journal on Imaging Sciences.*
2. D-N. Hsieh, S. Arguillère, N. Charon, L. Younes. Mechanistic Modeling of Longitudinal Shape Changes: equations of motion and inverse problems. *To appear in SIAM journal on Applied Dynamical Systems.*
3. N. Charon, A. Islam and W. Zbijewski. Morphometric analysis of tibio-femoral osteoarthritis based on combined bone geometry and joint space maps. *Journal of Medical Imaging*, vol 8(4), pp 044001, 2021.
4. D-N. Hsieh, S. Arguillère, N. Charon, L. Younes. Diffeomorphic shape evolution coupled with a reaction-diffusion PDE on a growth potential. *Quarterly of Applied Mathematics.* 2021.

5. N. Charon and T. Pierron. On length measures of planar closed curves and the comparison of convex shapes. *Annals of Global Analysis and Geometry*, vol 60, pp 863-901. 2021.

6. M. Bauer, N. Charon, P. Harms and H-W. Hsieh. A numerical framework for elastic surface matching, comparison, and interpolation. *International Journal of Computer Vision*, vol 129, pp 2425-2444, 2021.

7. H-W. Hsieh and N. Charon. Metrics, quantization and registration in varifold spaces. *Journal of Foundations of Comput. Maths*, vol 21, pp 1317-1361, 2021.

8. G. Li, M. Tang, N. Charon and C. Priebe. A Central Limit Theorem for Classical Multidimensional Scaling. *Electronic Journal of Statistics*, vol 14(1), pp 2362-2394, 2020.

9. E. Schwab, B. Haeffele, R. Vidal and N. Charon. Global Optimality in Separable Dictionary Learning with Applications to the Analysis of Diffusion MRI. *SIAM journal on Imaging Sciences*, vol 12(4), pp 1967-2008, 2019.

10. M. Bauer, M. Bruveris, N. Charon and J. Moeller-Andersen. A relaxed approach for curve matching with elastic metrics. *ESAIM: Control, Optimization and Calculus of Variations*, vol 25, 2019.

11. H-W. Hsieh and N. Charon. Diffeomorphic registration of discrete geometric distributions. *Mathematics of shapes and applications, Lecture Notes Series, Institute for Mathematical Sciences, National University of Singapore*, vol 37, 2019.

12. E. Schwab, R. Vidal and N. Charon. Joint Spatial-Angular Sparse Coding for dMRI with Separable Dictionaries. *Medical Image Analysis*, vol 48, pp 25-42, 2018.

13. N. Charon, B. Charlier and A. Trouvé. Metamorphoses of functional shapes in Sobolev spaces. *Journal of Foundations of Comput. Maths*, vol 18(6), pp 1535-1596, 2018.

14. S. Lee, M.L. Heisler, K. Popuri, N. Charon, B. Charlier, A. Trouvé, P.J Mackenzie, M. Sarunic and M.F. Beg. Age and glaucoma-related changes in retinal nerve fiber layer and choroid: point-wise analysis and visualization using functional shapes registration. *Frontiers of Neuroscience*, vol 11, pp 381, 2017.

15. C. Ragni, N. Diguet, J-F. Le Garrec, M. Novotna, T. Resende, S. Pop, N. Charon, L. Guillemot, L. Kitasato, C. Badouel, A. Dufour, J-C. Olivo-Marin, A. Trouvé, H. McNeill and S. Meilhac. Amotl1 mediates non-canonical Hippo signalling downstream of Fat4 to restrict heart growth. *Nature communications*, vol 8, pp 14582, 2017.

16. S. Lee, N. Charon, B. Charlier, K. Popuri, E. Lebed, M. Sarunic, A. Trouvé and M.F. Beg. Atlas-based Shape Analysis and Classification of Retinal Optical Coherence Tomography Images using the Functional Shape (fshape) Framework. *Medical Image Analysis*, vol. 35, pp 570-581, 2017.

17. N. Charon, B. Charlier and A. Trouvé. The fshape framework for the variability analysis of functional shapes, *Journal of Foundations of Comput. Maths*, vol 17, pp 287-357, 2017.

18. S. Durrleman, M. Prastawa, N. Charon, J.R. Korenberg, S. Joshi, G. Gerig and A. Trouvé. Defor-metrics : morphometry of shape complexes with space deformations. *Neuroimage*, vol 101, pp. 35-49, 2014.

19. N. Charon and A. Trouvé. Functional currents : a new mathematical tool to model and analyse functional shapes. *Journal of Mathematical Imaging and Vision*, vol 48, pp 413-431, 2014.

20. N. Charon and A. Trouvé. The varifold representation of non-oriented shapes for diffeomorphic registration. *SIAM journal on Imaging Science*, vol 6, pp 2547–2580, 2013.

21. N. Charon and F. Barbaresco. A new approach for target detection in radar images based on geometric properties of covariance matrices' spaces. *Traitement du signal*, vol 26, pp 269-278, 2009.

Conference and proceedings articles

1. E. Hartman, Y. Sukurdeep, N. Charon, E. Klassen and M. Bauer. Supervised deep learning of elastic SRV distances on the shape space of curves. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, pp 4425-4433, 2021.

2. H-W. Hsieh and N. Charon. Diffeomorphic registration with density changes for the analysis of imbalanced shapes. *International Conference on Information Processing in Medical Imaging*, pp 31-42, 2021.

3. D. Poinapen, T. Yoshizawa, Y. Zhou, N. Charon, S. Mou, K. Oshima, L. Wood, R. H. Hruban, W. Zbijewski. Three-dimensional shape and topology analysis of tissue-cleared tumor samples. *Proceedings of the SPIE conference on Medical Imaging*, vol 11603. 2021.

4. R. Shankar, H-W. Hsieh, N. Charon and A. Venkataraman. Multi-speaker Emotion Conversion via Latent Variable Regularization and a Chained Encoder-Decoder-Predictor Network. *Proc. Interspeech*. 2020.

5. Y. Sukurdeep, M. Bauer and N. Charon. An inexact matching approach for the comparison of plane curves with general elastic metrics. *Proceedings of ASILOMAR conference on Signals, Systems & Computers*, 2019.

6. M. Bauer, N. Charon and P. Harms. Inexact elastic shape matching in the square root normal field framework. *Geometric Science of Information*, pp 13-20, 2019.

7. R. Shankar, H-W. Hsieh, N. Charon and A. Venkataraman. Automated Emotion Morphing in Speech Based on Diffeomorphic Curve Registration and Highway Networks. *Proc. Interspeech* 4499-4503, 2019.

8. D-N. Hsieh, S. Arguillère, N. Charon, M.I. Miller, L. Younes. A Model for Elastic Evolution on Foliated Shapes. *International Conference on Information Processing in Medical Imaging*, pp 644-655, 2019.

9. E. Schwab, R. Vidal and N. Charon. (k,q)-Compressed Sensing for HARDI with Joint Spatial-Angular Sparsity. *Computational Diffusion MRI*, pp 21-35, 2018.

10. M. Bauer, M. Bruveris, N. Charon and J. Moeller-Andersen. Varifold-based matching of curves via Sobolev-type Riemannian metrics. *Graphs in Biomedical Image Analysis, Computational Anatomy and Imaging Genetics*, pp 152-163, 2017.

11. K. Kutten, N. Charon, M.I. Miller, J.T. Ratnanather, J. Matelsky, A.D. Baden, K. Lillaney, K. Deisseroth, L. Ye and J. Vogelstein. A Large Deformation Diffeomorphic Approach to Registration of CLARITY Images via Mutual Information. *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp 275-282, 2017.

12. I. Kaltenmark, B. Charlier and N. Charon. A general framework for curve and surface comparison and registration with oriented varifolds. *Computer Vision and Pattern Recognition*, 2017.

13. E. Schwab, N. Charon and R. Vidal. Spatial-Angular Sparse Coding for HARDI. *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp 475-483, 2016.

14. K. Kutten, J. Vogelstein, N. Charon, L. Ye, K. Deisseroth and M.I. Miller. Comparison of methods for annotating CLARITY mouse brain images. *Optics, Photonics and Digital Technologies for Imaging Applications*, 2016.

Book Chapters

1. M. Bauer, N. Charon, E. Klassen and A. Le Brigant. Intrinsic Riemannian metrics on spaces of curves: theory and computation. *Handbook of Mathematical Models and Algorithms in Computer Vision and Imaging*, pp 1-35, 2021.

2. N. Charon, B. Charlier, J. Glaunès, P. Gori and P. Roussillon. Fidelity metrics between curves and surfaces: currents, varifolds and normal cycles. *Riemannian Geometric Statistics in Medical Image Analysis*, pp 441-477, 2020.

3. M. Bauer, N. Charon and L. Younes. Metric Registration of Curves and Surfaces using Optimal Control. *Handbook of Numerical Analysis*, 2019.

Papers in preparation

1. H-W. Hsieh and N. Charon. Weight metamorphosis of varifolds and the LDDMM-Fisher-Rao metric.

2. R. Shankar, H-W. Hsieh, N. Charon and A. Venkataraman. A Diffeomorphic Flow-based Variational Framework for Multi-speaker Emotion Conversion.

Softwares

- Elastic weighted shape graph matching (ShapeGraph_H2match), co-developer. Website: https://github.com/charoncode/ShapeGraph_H2match. 2021.
- Diffeomorphic registration of varifold (Var-LDDMM), co-developer. Website: https://github.com/charoncode/Var_LDDMM. 2020.
- Square root normal field elastic shape analysis of surfaces (SRNFmatch), co-developer. Website: https://github.com/SRNFmatch/SRNFmatch_code. 2020.
- Riemannian shape analysis with second order Sobolev metrics (H2metrics), co-developer. Website: http://github.com/h2metrics/h2metrics. 2018.
- Functional Shapes Toolkit (FshapesTk), co-developer. Website: https://github.com/fshapes/fshapesTk. 2014 (latest version 2017).

C. Scholarly presentations

Invited conference and seminar talks

- Information Processing in Medical Imaging (IPMI), held remotely (June 2021).
- SIAM conference on Mathematics of Data Science, held remotely (June 2020).
- Applied Mathematics and Statistics department seminar, Johns Hopkins University (January 2020).
- ASILOMAR conference on Signals, Systems, and Computers, Pacific Grove (November 2019).
- Geometric Science of Information, Toulouse, France (August 2019).
- Maths in the Desert, Utah (May 2019).
- Mathematics colloqium, Florida State University (April 2019).
- AMS Joint Mathematics Meeting, session on Statistical, Variational, and Learning Techniques in Image Analysis, Baltimore (January 2019).
- Shape Analysis, Stochastic Mechanics and Optimal Transport workshop, Banff, Canada (December 2018).
- Maths in the black forest: workshop on new directions in shape analysis , Germany (July 2018).
- SIAM conference of Imaging Sciences, Bologna, Italy (June 2018).
- Journée de l'équipe Modélisation Mathématique et Calcul Scientifique, Lyon, France (December 2017).

- MINDS institute inaugural symposium, Baltimore (November 2017).
- Workshop on "Applications-Driven Geometric Functional Data Analysis", Tallahassee (October 2017).
- Medical Imaging and Computer Assisted Intervention (MICCAI), Quebec, Canada (September 2017).
- Computer Vision and Pattern Recognition (CVPR), Honolulu (July 2017).
- SIAM annual meeting, Pittsburgh (July 2017).
- AMS Sectional Meeting symposium on "Geometry and Topology in Image and Shape Analysis", Raleigh (November 2016).
- IMS Shapes and Application seminar, Singapore (July 2016).
- SIAM conference on Imaging Sciences, Albuquerque (May 2016).
- 8th International Congress on Industrial and Applied Mathematics, minisymposium 'Regularization methods for biomedical image analysis on manifolds', Beijing, China (2015).
- 8th International Congress on Industrial and Applied Mathematics, minisymposium 'Theoretical and computational aspects of geometric shape analysis', Beijing, China (2015).
- Applied Maths. Department seminar, Johns Hopkins University (2015).
- Congrès franco-roumain des Mathématiques appliquées, Université de Lyon, France (2014).
- SIAM conference of Imaging Sciences, Hong-Kong (2014).
- Presentation to the CIS seminar, Johns Hopkins University, Baltimore (2014).
- Presentation to the image group seminar in DIKU, University of Copenhagen, Denmark (2013).
- Presentation to MAP5 seminar, Université Paris Descartes, France (2013).
- Shape FRG meeting, Johns Hopkins University, Baltimore (2013).
- Presentation to the image seminar , Université Paris-Dauphine, Paris, France (2013).
- Workshop SIGMA'2012 , CIRM Marseille, France (2012).
- International Conference on Mathematical Methods for Curves and Surfaces , Oslo, Norway (2012).
- Séminaire Landau , Université Rennes 1, France (2012).
- Shape FRG meeting, ENS Cachan, Paris, France (2012).
- SMAI poster session, Guidel, France (2011). Awarded best poster prize.
- Shape FRG meeting, Imperial College, London, UK (2011).

D. Grants and funding

Awarded

- Collaborative Research: Data-Driven Elastic Shape Analysis with Topological Inconsistencies and Partial Matching Constraints. Institute: NSF. Role: PI. Amount: $\$149,998$. Start date: 09/01/2020. End date: 08/31/2023.
- CAREER: Shape analysis in submanifold spaces: new directions for theory and algorithms. Institute: NSF. Role: PI. Amount: $\$451,186$. Start date: 02/01/2020. End date: 01/31/2025.
- Individualized spatial topology in functional neuroimaging. Institute: NIH (R01). Role: co-I. Amount: $\$673,914$. Start date: 07/18/2018. End date: 03/31/2022.
- A general and efficient framework for computational shape analysis through geometric distributions. Institute: NSF. Role: PI. Amount: $\$217,969$. Start date: 07/01/2018. End date: 06/30/2020.

Pending

- FRG: Collaborative Research: Modeling geometric data: theory, computation and applications. Institute: NSF. Role: co-PI. Amount: $\$698,622$.

E. Research advising

PhD students

Current:

1. Yashil Sukurdeep. PhD candidate in Applied Mathematics and Statistics. Spring 2019-present.

Graduated:

1. Dr. Evan Schwab. PhD in Electrical and Computer Engineering (co-advised with Pr. Rene Vidal). Fall 2015-2017.
   Thesis title: Joint Spatial-Angular Sparse Coding, Compressed Sensing, and Dictionary Learning for Diffusion MRI.
   Defense date: 10/19/2017.
2. Dr. Dai-Ni Hsieh. PhD in Applied Mathematics and Statistics (co-advised with Pr. Laurent Younes). Fall 2017-2021.
   Thesis title: On model-based diffeomorphic shape evolution and diffeomorphic shape registration.
   Defense date: 06/08/2021.
3. Dr. Hsi-Wei Hsieh. PhD in Applied Mathematics and Statistics. Fall 2016-2021.
   Thesis title: Analysis of Geometric Shapes with Varifold Representation.
   Defense date: 06/21/2021.

Thesis defense committee member:

1. Dr. Xiyuan Wang: PhD in Mathematics.
   Thesis title: Topics in Galois representations
   Defense date: 05/06/2021.
2. Dr. Jingyi Zhu. PhD in Applied Mathematics and Statistics.
   Thesis title: Error bounds and applications for stochastic approximation with non-decaying gain
   Defense date: 02/17/2020.
3. Dr. Zachary Lubberts. PhD in Applied Mathematics and Statistics.
   Thesis title: Generating tight wavelet frames from sums of squares representations.
   Defense date: 03/13/2019.
4. Dr. Mingyue Gao. PhD in Applied Mathematics and Statistics.
   Thesis title: On Manifold Learning Subsequent Inference.
   Defense date: 03/04/2019.
5. Dr. Theodore Drivas. PhD in Applied Mathematics and Statistics.
   Thesis title: Anomalous Dissipation, Spontaneous Stochasticity and Onsager's Conjecture.
   Defense date: 04/27/2017.
6. Dr. Kwame Kutten. PhD in Biomedical Engineering.
   Thesis title: A Large Deformation Diffeomorphic Approach to Inter-modality Registration of Microscopy Image Volumes with Mutual Information Matching.
   Defense date: 01/31/2017.
7. Dr. Graham Beck. PhD in Applied Mathematics and Statistics.
   Thesis title: Planar Homography Estimation from Traffic Streams via Energy Functional Minimization.
   Defense date: 02/05/2016.

Masters students

1. Yanzong Yu. M.S in Data Science at Johns Hopkins University. Summer 2021.
2. Thomas Pierron. M.S student in mathematics from Ecole Normale Supérieure de Cachan. Summer 2020.
3. Mathilde Bateson. M.S student in mathematics, vision and learning from Ecole Normale Supérieure de Cachan. Summer 2017.
4. Vianney Debavelaere. M.S student in mathematics from Ecole Normale Supérieure de Cachan. Summer 2016.

Undergraduate students

1. Asef Islam (co-advised with Wojtek Zbijewski). B.S student in Biomedical engineering, Johns Hopkins University. 2018-2019.

F. Courses taught

At Johns Hopkins University:

1. EN.553.291: Linear Algebra and Differential Equations. Fall 2019, 2020.
   Systems of linear equations. Matrices and matrix operations. Linear Independence. Nonsigular matrices and matrix inversion. Subspaces, span, bases, nullspace and range. Orthogonality, projection and Gram-Schmidt procedure. Characteristic polynomials, eigenvalues and eigenspaces. Diagonalization of real symmetric matrices.
   Differential equations: separable and linear first-order DEs. Slope fields, Euler's method. 2nd and higher order linear DEs. Method of undetermined coefficients and variation of parameters. Systems of DEs: resolution by matrix exponentials and Laplace transforms.
2. EN 553.701: Real Analysis: Preparation for the Ph.D. Introductory Examination. Fall 2018.
   Topology of the real line: sequences, series, convergence and completeness. Topology of metric spaces: complete sets, connected sets, compact sets. Functions on metric spaces: continuity, uniform continuity, fixed point theorems. Sequences and series of functions: pointwise, uniform convergence, Stone-Weierstrass and Ascoli theorems, power series. Differentiability and integration of multivariate functions. Fourier series and Fourier transform.
3. EN 553.797: Introduction to control theory and optimal control. Spring 2018, 2019, 2020, 2021.
   General ordinary differential equations: existence, uniqueness of local and global solutions. Controllability of linear control systems: Kalman rank condition, constrained and time-dependent systems. Optimal control for linear systems: time optimality and linear-quadratic problems. Non-linear optimal control problems: weak and strong Pontryagin maximum principle, Hamilton-Jacobi-Bellman equations. Numerical methods for optimal control: direct, shooting and dynamic programming methods.
4. EN 550.681: Numerical Analysis. Fall 2016, 2017.
   Computer arithmetics and numerical instability. Numerical solutions to nonlinear systems of equations: fixed point, Newton, quasi-Newton methods, Laguerre method. Matrix linear algebra for linear systems of equations and eigenvalue problems. Interpolation and approximation of functions. Numerical PDEs: finite difference and finite element methods.
5. EN 550.493/693: Mathematical Image Analysis. Spring 2015, 2016, 2017.
   Digital images acquisition and modeling. Continuous and Discrete Fourier transform, applications to linear filtering and image compression. Variational methods for image denoising and deblurring. Image segmentation: thresholding methods, Chan-Vese model and variants. Introduction to wavelets and wavelet transforms.

At University of Copenhagen:

1. Signal and image processing (computer science masters program). Fall 2014. Co-taught with Jon Sporring.

At Ecole Normale Supérieure de Cachan:

1. Numerical analysis (masters level). Fall 2010. Co-taught with Frédéric Pascal.
   Matrix linear algebra: exact and iterative methods for linear systems, eigenvalue problems. Polynomial interpolation and approximation.
2. Complex analysis (senior undergraduate level). Spring 2011, 2012.
   Complex differentiable functions and Cauchy-Riemann equations. Path integrals of complex functions: index, homotopy, Cauchy theorem. Properties of holomorphic functions: analyticity, isolated zeros, maximum principle. Meromorphic functions and the residue theorem. Riemann theorem for simply connected sets of the complex plane.
3. Differential calculus (undergraduate level), Fall 2010, 2011, 2012. Co-taught with Frederic Pascal.
   Multivariate functions: differential map, partial derivatives, fixed point theorems, inverse function theorem. Notions on general ODEs: Cauchy-Lipschitz theorem, explosion theorem. Introduction to submanifolds and optimization on submanifolds.

G. Professional service

Seminars

- Organizer of the minisymposium "Shape Matching, Shape Analysis, and Morphometry: Theory, Numerics, and Applications" at the upcoming SIAM conference of Imaging Sciences (2022).
- Chair of the "Registration" session at the Information Processing in Medical Imaging conference (2021).
- Co-organizer and chair of the "Shape space" session at Geometric Science of Information conference (2019).
- Organizer of the minisymposium on "Geometric methods for shape analysis with applications to biomedical imaging and computational anatomy" at SIAM conference of Imaging Sciences (2018).
- Organizer of the minisymposium on "Recent advances in theoretical and computational shape analysis, applications to biomedical imaging" at SIAM annual meeting (2017).
- Organizer of the minisymposium on "Computational methods for the processing of diffusion MRI data and the analysis of brain connectivity" at SIAM conference of Imaging Sciences (2016).

Reviewing activities

For journals and conferences:

- SIAM journal of Imaging Science (SIIMS).
- Transactions of Pattern Analysis and Machine Intelligence (TPAMI).
- International Journal of Computer Vision (IJCV).
- Discrete and Continuous Dynamical Systems (DCDS).
- Journal of Foundations of Computational Mathematics (JFoCM).
- Journal of Computational Geometry (JoCG).

- Journal of Mathematical Imaging and Vision (JMIV).
- ESAIM: Mathematical Modelling and Numerical Analysis (ESAIM: M2AN).
- Annals of Global Analysis and Geometry (AGAG).
- Astronomy and Computing (ASCOM).
- Computer Vision and Pattern Recognition (CVPR).
- Geometric Science of Information (GSI).

For grants institutes:

- National Science Foudation (NSF).
- Swiss National Science Foudation (SNSF).
- US Army research office.

University service

- AMS department communication committee member, 2019-2021.
- AMS department graduate admissions' committee member, 2015-2019 and 2021-2022.
- Faculty search committee member, 2016-2017 and 2020.
- AMS department diversity advocate, 2016-2019.
- Graduate Board Oral exam committee member of:
    1. Kaitlin Stouffer (PhD candidate in Biomedical Engineering), 2021.
    2. Dai-Ni Hsieh (PhD candidate in Applied Mathematics and Statistics), 2020.
    3. Ran Liu (PhD candidate in Biomedical Engineering), 2019.
    4. Michelle Lohr (PhD candidate in Applied Mathematics and Statistics), 2019.
    5. Vikram Chandrashekhar (PhD candidate in Biomedical Engineering), 2019.
    6. Jingyi Zhu (PhD candidate in Applied Mathematics and Statistics), 2017.
    7. Zachary Lubberts (PhD candidate in Applied Mathematics and Statistics), 2016.

Other

- Supervision of a high school student, Ananya Gottumukkala, for an internship (Summer and Fall 2021).
- Participant in the 2018 USA Science & Engineering Festival.
- National judge in the finals of the 2017 Siemens Competition in Math, Science and Technology.