# Special Topic School Bonn

## New Mathematical Methods in Geometry Processing

**Day 1**
Monday, May 18, 2026

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| 08:15 – 09:00 | Self-registration | |
| 09:15 – 10:15 | Lecture: Neural Explicit Representations<br>*We start by exploring how neural networks can explicitly parametrize surfaces while handling surfaces with different genus mapping 2D domains to complex 3D shapes. We will review how these overfitted representations provide direct access to the first and second fundamental forms, ultimately enabling the construction of a continuous Laplace neural/shape operator.* | Niloy Mitra |
| 10:15 – 10:45 | –Break– | |
| 10:45 – 11:45 | Lecture: Introduction to geometric deep learning for surfaces<br>*The course will be divided in two parts: introduction to surface representations (point cloud, meshes) and discretizations of simple quantities. The second part will introduce deep learning (MLP, CNNs, transformers) and the challenges associated to geometric deep learning on surfaces. It is possible that the course will finish during the second lecture.* | Emery Pierson |
| 12:00 – 13:30 | –Lunch Break– | |
| 13:30 – 14:30 | Fast Forward Session | |
| 14:30 – 15:00 | –Break– | |
| 15:00 – 16:00 | Fast Forward Session | |

**Day 2**
Tuesday, May 19, 2026

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| 09:00 – 10:00 | Lecture: Recognizing Convex Structure in Geometry Problems<br>*We motivate our discussion by developing intuition for the space of convex optimization problems, motivated by function smoothing, shortest path computation, and other problems in geometry. We will see that a rich class of problems can be understood through the lens of convex optimization; moreover, even when a problem is not obviously convex, a series of strategies can be used to derive a convex relaxation whose solution may approximate the solution to or even solve the original problem.* | Justin Solomon |
| 10:15 – 11:15 | Lecture : Neural Implicit Representations<br>*We shift focus to implicit neural fields and their roots in classical geometry, highlighting why they are so popular for high-fidelity shape generation and 4D animation. We will discuss why extracting a clean, usable surface from these implicit mathematical volumes remains a non-trivial computational challenge, especially for modern learning setups.* | Niloy Mitra |
| 11:15 – 11:45 | –Break– | |
| 11:45 – 12:45 | Lecture: Geometric deep learning for point clouds<br>*The course will propose to review the most popular approaches for learning on point clouds: PointNet and variants, and recent transformers.* | Emery Pierson |
| 13:00 – 15:00 | –Lunch Break– | |
| 15:00 – 16:00 | Lecture / Lab<br>*We will numerically compute the first/second fundamental forms on trained neural surfaces. Participants will be able to try their own neural operators and gain hands-on experience performing differential operations within neural frameworks.* | Niloy Mitra |
| 16:00 – 16:30 | –Break– | |
| 16:30 – 17:30 | Open Problem Session | |
| 17:30 – 21:00 | –Get-Together– | |

**Day 3**
Wednesday, May 20, 2026

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| 09:00 – 10:0 | Lecture: Curves in Probability Spaces<br>*The course deals with absolutely continuous curves in Wasserstein spaces, their continuity equation and flow equation and special curves induced by couplings from optimal transport.* | Gabriele Steidl |
| 10:15 – 11:15 | Lecture: Solving surface PDEs using neural representations<br>*We conclude by bridging the gap between geometry and physics by demonstrating how to solve partial differential equations (PDEs) directly on neural manifolds. We will show early efforts on mesh-free methods that can simulate complex physical phenomena without the traditional challenges of mesh discretization.* | Niloy Mitra |
| 11:15 – 11:45 | –Break– | |
| 11:45 – 12:45 | Lecture: Discretization and Convex Optimization on Meshes and Graphs<br>*In this lecture, we will see how convex optimization can be applied to problems in geometry processing, whose unknowns are typically associated to elements of a point cloud, graph, or mesh. We will show that geodesic computation, optimal transport, edge-preserving smoothing via total variation, and skinning weights computation reduce to finite-dimensional convex problems that can be tackled with standard solvers.* | Justin Solomon |
| 13:00 – 14:30 | –Lunch Break– | |
| 14:30 – 17:30 | Excursion | |

**Day 4**
Thursday, May 21, 2026

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| 09:00 – 10:00 | Lecture: Flow Matching<br>*We introduce the flow matching for generative modelling and show the relation to score based diffusion.* | Gabriele Steidl |
| 10:15 – 11:15 | Lecture: Geometric deep learning for surfaces<br>*The course will present the main approaches for learning approaches: early failures, DiffusionNet, Jacobian fields.* | Emery Pierson |
| 11:15 – 11:45 | –Break– | |
| 11:45 – 12:45 | Lecture: Convex Relaxations for Geometric Reasoning<br>*Next, we will study how convex relaxation techniques lead to tractable formulations of challenging computational geometry problems. We will start with early examples of linear program relaxations for consistent segmentation and conclude with modern research using semidefinite and sum-of-squares relaxations to tackle particularly challenging problems in computer-aided design and surface matching. We will see that convex relaxations can be unreasonably effective in geometry, motivating open questions regarding the tightness of typical relaxations in this domain.* | Justin Solomon |
| 13:00 – 15:00 | –Lunch Break– | |
| 15:00 – 16:00 | Lecture / Lab: Generative Modelling<br>*In this lab lecture, you can try our generative modelling programs and investigate the role of different latent spaces.* | Jannis Chemseddine |
| 16:00 – 16:30 | –Break– | |
| 16:30 – 17:30 | Lecture: Geometrically Consistent 3D Shape Matching<br>*The aim of 3D shape matching is to establish correspondences between semantically similar regions across given surfaces. A desirable property of resulting matchings is geometric consistency, which means that correspondences preserve the neighbourhood relation between shape elements. Yet, in practice, geometric consistency is often overlooked, or only achieved under severely limiting assumptions (e.g. a good initialisation). This lecture will take on a discrete view and cover graph-based formalisms for geometrically consistent shape matching, including foundations on general assignment problems, product graph formalisms for 1D, 2D and 3D matching, as well as recent developments towards globally optimal 3D shape matching with geometric consistency.* | Florian Bernard |

| **Day 5**<br>Friday, May 22, 2026 | | |
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| 09:00 – 10:00 | Lecture: Discrete Flow Matching<br>*Finally, we will deal with discrete flow matching which plays a role when sampling from discrete distributions and can be used e.g. in large language models.* | Gabriele Steidl |
| 10:15 – 11:15 | Lecture / Lab: Open challenges<br>*We conclude by a summary of the course: what are the "solved challenges", and what is remaining - "open challenges", namely: learning high freqency information (details), large scale learning (linked to transformers, also multimodality), transformers for meshes (how to tokenize? how to adapt attention to surfaces?), generative modeling (how to generate a surface/mesh?), other representations (e.g. CAD).* | Emery Pierson |
| 11:15 – 11:45 | –Break– | |
| 11:45 – 12:45 | Lecture: Infinite-Dimensional Convex Models and Modern Parameterizations<br>*We will conclude our discussion of convex models by considering optimization problems for unknown functions, kernels, measures, currents, and other infinite-dimensional objects common in statistics, calculus of variations, measure-valued optimization, and PDE.* | Justin Solomon |