

Student Research Projects - Topics

Research Station Geometry+Dynamics

Starting winter term 2026/27

1 Bicycle mathematics - discrete or not

Supervisor: Peter Albers

Prerequisites: Grundlagen der Geometrie und Topologie

Abstract: A simple model of bicycle kinematics is the following: A bicycle is represented by an oriented line segment of constant length ℓ , which can move in such a way that the velocity of its rear wheel always points in the direction of the segment (the rear wheel is rigidly attached to the bicycle frame). The motion takes place in the Euclidean plane, but it can equally well - although with less physical motivation - be considered in \mathbb{R}^n .

The goal is to understand this (discrete and/or continuous) transformation and to visualize and simulate it through examples.

Literature and further reading:

- S. Tabachnikov: On the bicycle transformation and the filament equation: results and conjectures, arXiv:1602.06455
- S. Tabachnikov, E. Tsukerman: On the discrete bicycle transformation, arXiv:1211.2345

2 3D models of geometric objects

Supervisor: Florent Schaffhauser

Prerequisites:

- Adequate for 3rd semester Bachelor students and beyond.
- An interest in learning to use 3D printing software.

Abstract: The Heidelberg Experimental Geometry Lab has an extensive collection of 3D printed models, whose many interesting properties are nonetheless not immediately visible! In this survey project, we ?reverse engineer? the construction of the model and establish a protocol for the creation of future 3D models. Questions to be answered are:

- What is this object?
- How was it discovered in the first place?
- What are its mathematical properties?
- How is the model built in practice?

The student(s) working on this project will explore and enrich the HEGL gallery of 3D printed objects while documenting their process on the HEGL website. The expected output is a new 3D model, which will be accompanied by a blog post and added to the Lab's collection!

Literature and further reading:

- Check out our cool gallery of 3D printed models on the HEGL website!

3 Approximating Planar Conformal Shape Transformations

Supervisor: Christoph Schnörr

Prerequisites:

- LA/Ana
- programming skills
- complex analysis would be beneficial

Abstract: Conformal maps including the Riemann mapping theorem have beautiful general mathematical properties. Yet naive discretizations of closed-form relations are plagued by difficulties, like the crowding phenomenon. This project examines recent progress towards reliable numerical realizations and approximation. The long-term motivation for this project concerns mathematical shape representations which support machine-learning based shape recognition.

Literature and further reading:

- S. R. Bell. *The Cauchy Transform, Potential Theory and Conformal Mapping*. CRC Press, 2nd edition, 2016.
- N. Dym, R. Slutsky, and Y. Lipman. Linear Variational Principle for Riemann Mappings and Discrete Conformality. *PNAS*, 116(3):732–737, 2019.
- A. Gopal and L. N. Trefethen. Representation of Conformal Maps by Rational Functions. *Numerische Mathematik*, 142:359–382, 2019.
- Q. Chang, C. Gotsman, and K. Hormann. Real-Time Conformal Maps and Parametrizations. *Computer Graphics Forum*, (e70310), 2026.

4 Web-App for shadows in Coxeter groups

Supervisor: Petra Schwer

Prerequisites: Students interested in this project should ideally bring at least one of the following:

- Solid knowledge on Coxeter groups e.g. as covered in the course *Coxeter groups and buildings* taught in the summer term 2026, or
- Solid knowledge about and experience in programming in java-script and HTML.

Abstract: We host a web-app showing Bruhat intervals and various kinds of other shadows in Coxeter groups. In small dimensions these objects can be visualized as combinatorially defined sub-patterns of the tilings of the hyperbolic plane or euclidean 2-space.

You can find and play with the applet under the link listed below in the literature section. The main goal of the project is to improve and enrich the functionality of the applet which is currently in use for ongoing research. Depending on time and students interest and prior knowledge we may also think about research questions related to these objects.

Literature and further reading:

- <https://www.mathi.uni-heidelberg.de/~reflectiongroupsnetwork/shadows/shadows.html>.
- Björner, Brenti: *Combinatorics of Coxeter groups*, Springer 2005.
- Brown, *Buildings*, Springer, 1989. (See also here: <https://pi.math.cornell.edu/~kbrown/buildings/>)