Discrete Random Structures: Enumeration and Scaling Limits
(SFB Research Network funded by Austrian Science Fund (FWF))
https://SFBrandom.univie.ac.at/

We are currently advertising **eight postdoc positions**, associated with the above research network. Random discrete structures, which are ubiquitous in many areas of modern mathematics, are essential to describe a host of phenomena in mathematical physics. For instance they play a key role in our understanding of phase transitions, which describe how physical systems can undergo abrupt changes (as when water changes from liquid to solid state below 0C).

The research network focuses in particular on fundamental two-dimensional examples, including the celebrated dimer model and planar graphs. By combining probabilistic and combinatorial perspectives it is our aim to answer some of the most basic questions about these models: How to enumerate them, either exactly or approximately? How can one describe their random geometry in the large scale limit? How to explain that these structures keep arising under different guises in different problems? Such questions also have deep connections to questions in mathematical physics, from topological phase transitions to Liouville quantum gravity, which will also be investigated.

The 8 postdoc projects are:

1. **Random geometry of dimers and planar maps (Nathanael Berestycki, Network Coordinator, Univ. of Vienna).** The project focuses on the one hand on the dimer model (one of the most classical models of statistical mechanics) and on the other hand on random planar maps, a canonical notion of random surfaces. In both cases we will seek to derive explicit scaling limits which demonstrate the conformal invariance that these models are predicted to acquire in the fine mesh limit. We will also consider the question of the associated critical exponents, which on planar maps are believed to obey the KPZ (Knizhnik--Polyakov--Zamolodchikov) relation of Liouville quantum gravity.

2. **Additive functionals on random discrete structures (Michael Drmota, TU Wien).** This project deals with additive functionals (such as pattern or subgraph counts) on random planar maps and random planar graphs. The goal is to establish general central limit theorems for such functionals by applying different tools from combinatorics, probability theory and asymptotic analysis.

3. **Systematic approaches to bijective proofs (Ilse Fischer, Univ. of Vienna).** The focus is on developing systematic approaches for constructing bijective proofs from known computational proofs. This will be done along several (mostly longstanding) open problems related to the mysterious relation between plane partitions and alternating sign arrays. Among these problems are certain Littlewood-type identities related to alternating sign arrays, which is exciting as this might hint at an Robinson-Schensted-Knuth-type correspondence for alternating sign arrays.

4. **Phase transitions in random combinatorial structures (Mihyun Kang, TU Graz).** This project focuses on the universality for matchings on sparse random graphs. The main goals are to investigate how the uniqueness of the Gibbs measure over matchings on a sparse random graph is related to the criticality of the rank of a sparse random matrix and to determine the asymptotic number of maximum matchings in random subgraphs of lattice-like graphs.

5. **Tiling Enumeration (Christian Krattenthaler, Univ. of Vienna).** This project aims to develop methods for solving (exact and asymptotic) enumerative problems connected with domino tilings and rhombus tilings. In the centre of the project there is Ciucu's electrostatic conjecture on the asymptotic behaviour of the correlation of defects (gaps, holes) as the mutual distances of the defects tends to infinity. It predicts that this asymptotic correlation is given by the (exponential of the negative of) 2D Coulomb energy of the system of charges obtained by regarding each hole as a point charge.

6. **Dimers beyond planarity (Marcin Lis, TU Wien.)** This project aims to study the dimer model beyond the exactly solvable planar case. More concretely we will investigate questions of existence of phase transitions, and establishing the scaling limit of a dimer model on a two-dimensional slab. We conjecture that the model undergoes a BKT-type phase transition between a localised and a delocalise phase, and in the latter regime its fluctuations should be given by the Gaussian free field in the scaling limit.

7. **Asymptotic enumeration and study of discrete structures (Benedikt Stufler, TU Wien).** This project deals with the asymptotic enumeration of discrete structures and the study of shape characteristics when generated at random. Our main focus is on Pólya structures and symmetries of graphs which greatly complicate the task of asymptotic enumeration. In particular, while the asymptotic number of labelled planar graphs of a given size has been determined in recent breakthrough work, determining the number and shape of unlabelled planar graphs and related classes such as 3-regular planar graphs remains a major open problem. Our goal is to resolve this and, building on that, study their properties when generated at random.

8. **Dimer model: dynamics and scaling limits (Fabio Toninelli, TU Wien).** This project, at the interface between probability theory and mathematical physics, focuses on Markov (Glauber) dynamics of statistical physics models. The main goals are the mathematical understanding of mixing properties of the dynamics (speed of convergence to equilibrium, cutoff phenomena, dynamical phase transitions) and of the emergence of large-scale limits (hydrodynamic limits, fluctuation process). One of the goals is to investigate ergodicity and fast mixing of the Glauber dynamics of the dimer model, beyond the usual planar bipartite setting.

The advertised positions are associated either to the Faculty of Mathematics of the University of Vienna, to the Faculty of Mathematics and Geoinformation of the TU Wien, or to the Faculty of mathematics at the TU Graz.

The extent of employment is 40 hours per week with no teaching obligations, and the salary (expected to be around €66.000 gross per year) includes full social security. The positions are for a duration of two years with a possibility of extension. The positions will start on 01 June 2024 or later.

Application Requirements and Procedure

The basic requirement for the advertised positions is a very good working knowledge in the fields connected to the projects. The candidates must have a PhD degree (or equivalent) in Mathematics at the moment the position starts. The application should contain:

- a motivation letter, that indicates clearly for which of the postdoc projects the candidate is applying; in case of application to more than one project, the letter should indicate an order of preference;
- a scientific CV with publications list;
- a research statement;
- At least two letters of recommendation sent directly to SFBrandom.mathematik@univie.ac.at by the persons writing the letters.
- The deadline for applications and for letters is **January 21st, 2024.**

Applications shall be uploaded at

https://SFBrandom.univie.ac.at/open-positions-available/postdoc-application/