Institute of Mathematics – Phd topics - SH

1/ Supervisor: Márton Naszodi, Phd

Topic: Covering problems in discrete geometry

Knowledge of English: at least B2 level

Place of research: ELTE, Institute of Mathematics, Department of Geometry

email: marton.naszodi@math.elte.hu

Description: The idea is to explore how tools from combinatorics and from probability can be applied to understand high dimensional convex bodies, with special emphasis on covering problems. Having a good understanding of (or an interest in) either combinatorics or functional analysis and probability is an asset, but is not required.

2/ Supervisor: Balázs Csikós, Phd

Topic: Harmonic manifolds

Description: Harmonic manifolds were introduced by E.T. Copson and H.S. Ruse in 1940. For a long time the only known examples of harmonic manifolds had been the 2-point homogeneous symmetric spaces, and Lichnerowicz conjectured that there are no other examples at all. Though the Lichnerowicz conjecture was proved by Z.I. Szabó for compact simply connected manifolds, E. Damek and F. Ricci found examples of non-compact harmonic spaces that are not symmetric. The aim of the research is to study geometrical properties of harmonic spaces with the final goal to obtain a classification of them: either to show that there are no harmonic spaces other than the ones mentioned above, or to find further examples.

Place of research: ELTE Faculty of Science, Institute of Mathematics, Department of Geometry

Knowledge of English required: at least B2 level

Professional requirements: solid knowledge of differential geometry (calculus on smooth manifolds) and Riemannian geometry

Supervisor's e-mail: csikos@cs.elte.hu

3/ Name (supervisor): Ferenc Izsák , Phd

Department: Dept. of Applied Analysis and Computational Mathematics

Title: **Fractional diffusion with Neumann type boundary conditions**

Description of the topic: In the theoretical and numerical study of the anomalous diffusion one important open problem is the treatment of Neumann boundary conditions. The proposed research topic is to develop a meaningful model of this and develop numerical simulations with a corresponding convergence theory. One can start with the one-dimensional case for inhomogeneous boundary conditions and move to the multidimensional case wth homogeneous conditions. Discrete stochastic simulations are also of interest.

Prerequisites: basic programming skills (Matlab is satisfactory) and basic PDE's and functional analysis

4**/ Name (supervisor)**: János Karátson , Dsc

Department: Dept. of Applied Analysis and Computational Mathematics

Topic: **Comparative analysis of some preconditioned iterative methods for PDEs**

Description: Preconditioned iterative methods form a basic tool for solving discretized elliptic partial differential equations, which also arise as a component of the solution process for time-dependent and nonlinear problems. The goal of this research is to improve and compare certain types of such methods (such as GMRES versus CGN under operator preconditioning, or nonlinear CG versus Newton type inner-outer iterations) for PDES arising from various applications.

professional requirements: good knowledge in numerical analysis of partial differential equations, and good programming skills in Matlab

5/ Name (supervisor): Gergely Zábrádi, Phd

Department: Algebra and Number Theory

Title: The p-adic Langlands programme

Description: The p-adic Langlands programme is a newly emerging task of fundamental importance on the frontier of number theory and representation theory. The goal is to match p-adic (and modulo p) representations of p-adic linear groups coming from automorphic forms with p-adic (and mod p) Galois representations of local fields, preferably in a functorial way. Functors in both directions have been constructed in recent years (through the work of Breuil, Colmez, Schneider, Vigneras, and the current supervisor), however, it is widely open whether they indeed realize such a correspondence. The project is to test these functors on certain automorphic/Galois representations, prove some conjectured properties of them, and hopefully construct special cases of a p-adic Langlands correspondence.

Prerequisites: solid knowledge of introductory algebraic number theory and of group representations is essential. Further background on algebraic geometry, homological algebra, and/or on local class field theory would also be welcome, but not necessary.

6/**Name (supervisor): Tamás Szőnyi, Dsc**

Department: Computer Science

Title: Finite Geometry

Description: Stability theorems for combinatorially defined substructures of finite geometries

Prerequisites: solid knowledge of algebra

Knowledge of English required

7/ **Name** (supervisor): **Zoltán Buczolich , Dsc**

Department: Analysis

Title: **Geometric and dynamical aspects of measure and real function theory**

Description: Research connected to the research areas of the advisor, that is, the areas of geometric measure theory, fractals, multifractals, ergodic theory, dynamical systems or classical real function theory. Details of the project are to be negotiated with the advisor.

Knowledge of English required

8/Name (supervisor): Péter Sziklai, Dsc

Department: Computer Science

Titel: Algebraic and combinatorial methods in symmetric structures

Description: We apply algebraic and combinatorial methods in symmetric structures, typically coordinatized by finite fields (e.g. linear, affine, projective spaces). One of the methods is based on the intensive use of polynomials over finite fields. There is an extensive international collaboration in this topic.

Required language: English

9/Name (supervisor): Miklós Arató, Phd

Department: Department of Probability Theory and Statistics

Titel: Statistical problems of Matern random fields

Description: Gaussian random fields with continuous parameters are the most important ingredient in spatial statistical modelling and geostatistics. The Matern family of spatial correlations is a flexible parametric class with one parameter determining the smoothness of the paths of the underlying spatial field.

In this project, we aim to investigate the properties of these fields and we are interested in constructing the estimators of the parameters.

References

Handcock, M. S. & Stein, M. L. (1993). A Bayesian analysis of kriging. Technometrics 35, 403-410

Peter Guttorp and Tilmann Gneiting (2006). Studies in the History of Probability and Statistics XLIX on the Matérn Correlation Family. Biometrika, Vol. 93, No. 4 (Dec., 2006), 989-995

Finn Lindgren and Håvard Rue (2011). An explicit link between Gaussian fields and Gaussian Markov random fields: the stochastic partial differential equation approach. J. R. Statist. Soc. B (2011) 73, Part 4, 423–498

Anderes, E. B. and Stein, M. L. (2011) Local likelihood estimation for nonstationary random fields. J. Multiv. Anal., 102, 505–520.

Required language: English

10/ Name (supervisor): Tibor Jordán, Dsc

Department: Operations Research

Topic: **Combinatorial rigidity**

Description: Rigidity and flexibility of structures is an exciting research area in the intersection of geometry, algebra, and combinatorics. Mathematicians have been interested in the rigidity of frameworks since Euler's conjecture from 1776, which stated that 3-dimensional polyhedra are rigid. The conjecture was verified for convex polyhedra by Cauchy in 1813 and for generic polyhedra by Gluck in 1975. Connelly constructed a counterexample to Euler's original conjecture in 1982. Interest and developments in rigidity have increased rapidly since the 1970's, motivated initially by the combinatorial characterization of rigid two-dimensional generic bar-and-joint frameworks by Laman in 1970, and also by applications in many areas of science, engineering and design.

Combinatorial rigidity refers to the part of rigidity theory which is concerned with those results and problems where the underlying combinatorial structure of the frameworks plays a key role. Maxwell pointed out, already in the 19th century, that one can deduce necessary conditions for the rigidity of a bar-and-joint framework by using properties of its underlying graph. Furthermore, the applications have encouraged mathematicians not only to develop theoretical results but also fast algorithms, e.g. for determining whether a given framework is rigid. These types of problems also made the combinatorial aspects (graph algorithms, combinatorial optimization) even more central.
Results of this field are often useful in other areas of discrete geometry as well.

The goal is to contribute to rigidity theory and its applications by new results in combinatorial rigidity.

Professional requirements: familiarity with the basic concepts and methods of discrete mathematics (graph theory and/or matroid theory), linear algebra,and geometry.

Required language: English, at least B 2 level

11/ Supervisor: Tamás Rudas

email: rudas.tamas@tk.mta.hu

Topic: Comparison of structural equation modeling and graphical modeling

Description: These two contemporary approaches to modeling the association structure of multivariate data use graphs to visualize the models, but attribute different interpretations to the graphs. The former aims at modeling direct effects, the latter emphasizes conditional independencies. SEM was originally designed for Gaussian data but extensions to deal with categorical data are available, GM can handle normal and discrete variables, and their mixtures, equally well. Both methods offer the possibility of path analysis. The research will establish the identical and different characteristics of these two approaches and will compare their usefulness in the analysis of various data sets.