Research activities at the Department encompass several main branches of pure and applied mathematics; namely algebra, topology, number theory, geometric analysis, mathematical analysis, statistics and mathematical modelling.

The Department provides teaching of professional mathematics (scholarly mathematics), mathematics aimed to finances and economy, and teaching of mathematics for future teachers in secondary schools. Our department also provides courses of mathematics for other branches at the Faculty of Science, such as physics, chemistry, biology, and geography. Furthermore, our members teach all main mathematical courses at the Faculty of Informatics and some mathematical courses at the Faculty of Economics and Administration. Our department has accreditation for the doctoral program of mathematics in

- algebra, number theory, and mathematical logic,
- geometry, topology, and global analysis,
- mathematical analysis,
- history of mathematics and mathematical education,
- probability, statistics, and mathematical modelling.

In cooperation with the university our department publishes the mathematical journal *Archivum Mathematicum*
(
http://emis.muni.cz/journals/AM/
). Moreover, the Editorial Office of the journal
Differential Geometry and its Applications
(
http://dga.math.muni.cz/
) published by Elsevier is located at the department. Both journals are indexed in the international databases Mathematical Reviews, Zentralblatt für Mathematik, and in Scopus.

The following working groups are currently active at the department. The contact information for the employees is here , including the link to the publications , grant projects , and teaching activities .

ALGEBRA, TOPOLOGY AND NUMBER THEORY

Category theory (J. Rosický, L. Vokřínek, M. Lieberman). The research is mainly oriented to accessible categories and their applications to algebra, algebraic topology and model theory. Topics like Abstract elementary classes, Quillen model categories and weak factorization systems are included. We also deal with applications of abstract homotopy theory to computational topology.

Number theory (R. Kučera, M. Bulant). The research activity is focused on algebraic number theory, especially on abelian fields. The main aim is the investigation of algebraic structures having connection to the class group of these fields (like the group of circular units or Stickelberger ideal).

Ordered sets (J. Paseka, D. Kruml). The research deals with connections of algebra with logic, in particular quantum, tense and fuzzy. The basic tool are residuated posets but the emphasis is also on quantales in connection with C*-algebras and noncommutative geometry.

Semigroup theory (O. Klíma, M. Kunc). The research is focused on equational characterizations of pseudovarieties of finite semigroups and on lattices of pseudovarieties. We also deal with applications of semigroups to formal languages, for instance to the effective characterization of clases of regular languages.

GEOMETRIC ANALYSIS

Geometric complex analysis (Martin Kolář, Ilya Kossovskiy). The research is focused on normal forms and invariants of domains in complex space and their boundaries, in particular in the presence of singularities. The team is also interested in connections with the theory of dynamical systems.

Lie theory, geometric theory of partial differential equations and geometric structures (Jan Slovák, Josef Šilhan, Katharina Neusser). The aim is to use effectively the algebraic representation theory of Lie groups and algebras in geometric analysis for a large class of seemingly unrelated geometries (e.g. Projective, conformal, CR, quaternionic), properties of (invariant) differential operators for such geometries, connections with subriemannian geometry and direct applications in algebraic geometry, geometric control theory, non-communttive differential geometry, computer vision, geometry of deep learning and information geometry.

Nonlinear partial differential equations (Phuoc Tai Nguyen) The research focuses on the existence, nonexistence, uniqueness, multiplicity, qualitative properties, and classification of solutions to nonlinear partial differential equations with singular coefficients and data. Our research interest also involves studying various aspects of equations in fluid dynamics, for example Navier-Stokes equations and Euler equations.

Natural operators and general geometric structures (Josef Janyška, Jan Slovák). The main object of interest of this group are general fibred spaces (jet bundles, Weil bundles, and natural bundles) invariant (i.e. geometric) operations on them, including those depending on special geometric structures, and applications of geometric methods in theoretical physics, in particular covariant classical and quantum theory on curved spacetime.

Geometric aspects of algebraic topology (Martin Čadek). The research concerns, on the one hand, algorithmic approach to solution of classical problems of algebraic topology (description of homotopy classes of mappings, deciding about homotopy equivalence of two mappings, or two simplicial complexes), on the other hand topological conditions for existence of various geometric structures on low dimensional manifolds.

MATHEMATICAL ANALYSIS

Nonlinear differential and difference equations (Miroslav Bartušek, Zuzana Došlá, Petr Hasil, Jiřina Šišoláková, Michal Veselý). The research is oriented towards the asymptotic theory of differential equations, including differential equations of non-integer orders and equations with delay. These equations have wide applications in natural and engineering sciences, medicine and economics. It mainly concerns the issue of asymptotics, oscillation and stability of solutions, and questions connected with boundary value problems on unbounded intervals and numerical discretizations of these equations. An important part of the research is the oscillation theory of semi-linear differential and difference equations of the Euler type.

Limit periodic and near-periodic systems (Petr Hasil, Michal Veselý). The core of this research is the analysis of the behavior of solutions of linear systems with non-periodic coefficients. Periodic (i.e. with periodic input data in the position of coefficients) differential and differential linear equations and systems belong to the most frequently used continuous and discrete models of various (not only natural) events. If the assumption of pure periodicity is replaced by the more general case of limit periodicity or quasi-periodicity of the studied

quantities, specific functions and sequences can be obtained as solutions to the considered equations and systems, which cannot be solutions in the strictly periodic case. This is consistent with observations in many situations where periodic models do not allow sufficiently accurate description of phenomena. Within the framework of the research, emphasis is placed on the study of those solutions that differ significantly from the solutions of periodic systems, i.e. on the description of sets of late-periodic and non-asymptotically early-periodic solutions.

Oscillation and spectral theory (Peter Šepitka, Roman Šimon Hilscher, Petr Zemánek). The main object of study is oscillation theory for linear differential and difference systems (especially Hamiltonian and symplectic systems), or more generally for systems defined on arbitrary hybrid time domains - so-called time scales. The studied systems are closely related to optimal processes in nature, science and technology. Research is further focused on the spectral properties of systems and associated operators or linear relations, e.g. on the Weyl-Titchmarsh theory. In our research, we also focus on applications in other areas of mathematics, e.g. in calculus of variations and optimal control, in linear algebra (matrix theory and their analytical properties), or in differential geometry (Maslov's index).

Calculus of variations and optimal control (Peter Šepitka, Roman Šimon Hilscher, Petr Zemánek, Tri Truong Van). It is a mathematical theory of first- and second-order optimality conditions for calculus of variations and optimal control optimization problems. The research concerns, for example, the following topics: necessary conditions of optimality, sufficient conditions of optimality, weak Pontryagin principle, isoperimetric problems or, more generally, problems with constraints, Hamilton-Jacobi theory (dynamic programming), linear-quadratic regulation problem (LQR problem), structure and solvability Riccati's equation. In the research, we consider continuous and discrete optimization tasks and their unified theory on time scales.

MATEMATICAL MODELLING AND STATISTICS

Matematical modelling (Lenka Přibylová, Veronika Eclerová, Deeptajyoti Sen, Jakub Záthurecký, Zdeněk Pospíšil, Jan Ševčík). Research activities are focused on the creation of deterministic stochastic mathematical models of real processes, their analysis, numerical simulation, and computer implementation (mathematical environments Matlab, R, Python, Julia, Matcont, Maple). It deals with models from the fields of biomedicine, neurophysiology, epidemiology, ecology, and economics. Mathematical models of the mentioned processes mainly use differential and difference equations, the theory of nonlinear dynamics, methods of numerical mathematics and statistics. Research activities are also focused on the development of mathematical theory in this area (https://science.math.muni.cz/ndteam/). The team members collaborate with, e.g., the University of Twente, University of Innsbruck, Faculty of Arts UK Prague, BUT, University of Defense, FN Brno, ÚZIS, Center for Modeling of

Biological and Social Processes BISOP, Institute of Information Theory and Automation of the Academy of Sciences of the Czech Republic, Biological Center of the Academy of Sciences of the Czech Republic, The Institute of Religious Studies of the FF MU, the Institute of Instrumentation of the Academy of Sciences of the Czech Republic and Bicont Laboratory, s.r.o.

Statistics and data analysis (Stanislav Katina, Jan Koláček, David Kraus, Andrea Kraus, Radim Navrátil, Iveta Selingerová, Jiří Zelinka, Marie Budíková, Ivana Horová, Ondřej Pokora). The team's research includes: parametric, non-parametric robust statistical methods, kernel smoothing, functional data analysis, survival analysis, temporal, spatial and spatiotemporal spline smoothing, shape and image analysis, statistical graphics, discriminant analysis, generalized linear models, statistical models for elliptic contour distributions, ROC curves, estimation and testing of procedures in unbalanced heteroscedastic models and models of parameter estimation of calibration function, statistical inference for stochastic processes, statistical inverse problems, stochastic models based on Brownian motion, Itô and diffusion processes, statistical assessment of reliability, time series analysis, signal processing, epidemic processes and models, branching processes, point processes, analysis of incomplete and missing data, epidemiological surveillance, design of clinical studies (oncology, Alzheimer's disease and others), statistical programming, implementation of R and MATLAB languages, and last but not least, the application on real data. The members of the team cooperate with many domestic and foreign institutions, among others with the Institute of Anthropology of Masaryk University, the Faculty Hospital of Anna, Masaryk Institute of Oncology, FN Brno, Veterinary and Pharmaceutical University Brno, University of Defense in Brno, Institute of Information Theory and Automation AS CR Prague; with the Institute of Informatics of the Academy of Sciences of the Czech Republic in Prague, the Orthopedic Clinic of the Jessenius Faculty of Medicine of the Comenius University in Martin, the Institute of Neuroimmunology of the Slovak Academy of Sciences in Bratislava, the East Slovak Institute for Cardiovascular Diseases and Medical Faculty of Pavol Jozef Šafárik University, Košice, Slovakia, The University of Glasgow (School of Mathematics and Statistics, Scotland, UK), with the Royal College of Surgeons in Ireland (Dublin, Ireland), Ecole Polytechnique Fédérale de Lausanne, Universität Bern, Universitätsspital Bern, Universitätsspital Zürich.

Digital City Lab (Stanislav Sobolevsky). This emerging lab focuses on data analytics with applications in urban development. Methods include artificial intelligence and deep learning on hierarchical graph structures. The research group initiates and enters multidisciplinary projects and focuses on stabilizing an international consortium of academic and commercial partners.

OTHER ACTIVITIES:

In the area of mathematical education (Jaromír Šimša, Roman Plch) we focus on problems of

high school mathematics and preparation of its teachers during their undergraduate and postgraduate studies. A special attention is devoted to problem solving strategies designed for gifted high-school students and to teaching mathematics in an E-learning environment.