CMAF-CIO: Report 2015

Here is a selection of topics of our activity in 2015.

Nonlinear PDEs and Applications

- Free boundary problems and phase change problems.
- Analysis of ground states of coupled Schrödinger systems.
- Cauchy problem for nonlinear coupled Schrödinger equations.
- Riemann problem for the Brio system with a Dirac mass and collision of δ and δ' waves.
- Mathematical methods in dislocation models: (i) Beltrami decomposition of symmetric tensors in Lebesgue spaces, (ii) functional approach to the incompatibility operator.
- A nonstationary mathematical model for a non-Newtonian Fluid, anisotropic, non dilating, in the presence of nonlinear forces.
- Linear conservation laws with bounds on the gradient of the solution.

Operations Research

- Reformulation of layered graphs for problems of vehicle routing (in partnership with researchers from the University of Vienna).
- Network design (in partnership with a researcher from the University of Montreal): relations between discretized models.
- Project and planning with limited resources (ongoing PhD).
- Design of network with restrictions; design of trees with diameter restrictions (also in collaboration with the University of Vienna).
- Combinatorial optimization problems with uncertainty (in collaboration with researchers from the Karlsruhe Institute of Technology, the Technical University of Catalunya, and the University of Valencia).

Within an applications-oriented trend we studied models of:

- Planning of rescue operations in passenger ship accidents (in collaboration with the portuguese Navy): an ongoing PhD thesis.
- Routing of fishing fleet survey vessels (in collaboration with the *Instituto Português do Mar e da Atmosfera* — Portuguese Institute for Sea and Atmosphere): one master's thesis.
- Scheduling of service drivers: meta-heuristics for sectorization in routing problems (a project for the municipality of the city of Seixal).
- Routing in networks operating under the protocol "Multiple Spanning Tree" (one doctoral thesis in the FUB (Free University of Brussels) co-supervised by a team member).
- Allocation of surgery blocks in hospitals (2 master's thesis).
- Scheduling of production in a lubricants refinery.
- Fuel blending in oil refineries (in collaboration with institutions from Iran and China).

Some group members have organized prestigious international events (e.g. NetOpt 2015).

Geometry

- Discretization of symmetry-preserving variational field theories.
- Classification of meromorphic rank-2 conexions within the complement of a cusp.
- Construction with straightedge and compass of a total spherical perspective with application to computer visualization.

- Riemann-Hilbert correspondence for twistor D-modules. Construction of the RH^S reconstruction functor. Characterization of S-perverse sheaves with perverse dual.

Some group members have organized international conferences in Padova and at the FCUL (Faculty of Sciences of the University of Lisbon).

Differential Equations and Dynamical Systems

- Epidemiology problems via PDEs: the role of heterogeneity.
- Kepler problem with drag.
- Singular problems: chaotic dynamics in the Kepler problem; Dirichlet and homoclinic solutions.
- Delay differential equations with impulses: global stability. Persistence and extinction.
- Lyapunov exponents of linear cocycles: big deviations towards singular analytic quasi-periodic cocycles. New results on SRB measures in polygonal dissipative billiards, evolutionary games, and graphs (isospectral theory).
- General theory of iterative functional equation systems.

Stochastic Analysis and Mathematical Physics

- Bifurcations in a Boltzmann model for alignment.
- No-arbitrage in 2 models with volatility driven by fractional noise.
- Explicit algebraic constructions of harmonic spheres in Lie groups and in symmetric spaces. Patterns of equations for the first non-trivial formulas.
- Isometric embedding of a Kähler manifold.
- Improvements on the estimates of the Varadhan convergence rate.
- Microscopic and mesoscopic limits in the dynamic Widom-Rowlinson model.

The group has organized an international conference at Universidade do Minho.

Mathematical Logic

Regarding the scientific work of 2015, we may emphasize the following. In Model Theory, a way of developing the formalism for the six Grothendieck operations on sheaves over semi-bounded and o-minimal structures was achieved; and the current project goal is to transfer the process for the Loeser and Hrushovski framework. In Proof Theory, we pursued the research in atomic polymorphism (on matters of "faithfulness", normalization, "instantiation overflow", etc.) and also in functional interpretations (particularly with relation to recent interpretations of non-standard arithmetic).

A member of the group has organized international workshops at Faculdade de Ciências da Universidade de Lisboa.

Biomathematics and Statistics

We studied the propagation and epidemiology of dengue. Using available data from the DenVaxia vaccine of Sanofi-Pasteur, we studied its impact, leading to surprising negative results on account of vaccine administration procedures recommended by the WHO. The positive impact was observed only under monitoring of the receivers' serological condition.

The group's experience in using mathematical models with complex dynamics and stochastic modelling including Bayesian statistics has allowed the correct evaluation of experimental data. Within the former

CMAF and presently CMAF-CIO, the group has been applying mathematical models to public health issues, engaging interdisciplinary research with international teams and publishing in journals of high impact factor.

We undertook statistical approaches (mixed and simple generalized linear models, and time series) to problems in the subjects of health, ecology and insurance.

On a more theoretical vein we developed, among others, spatial-temporal models based on jumps and polynomial waiting times for human mobility as a factor in disease dynamics, using fractional calculus as a model for superdiffusion.

In 2015 we organized the 6th edition of the DSABNS international workshop at the University of Lisbon.

Papers 2015

Nonlinear partial differential equations and applications

Papers in international journals/book

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