MATH AmSud
2021 call for proposal approved projects

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ALGonCOMB

Algebraic structures supported on families of combinatorial objects

The aim of this project is to study algebraic structures supported on families of combinatorial objects. We are interested in contributing to the current research trend where purely algebraic structures like associative algebras, Hopf algebras and operads are described and studied in terms of the combinatorics of objects like words, trees and walks on graphs. We will study different generalizations of associative, pre-Lie and dendriform algebras and their associated operads. Both the algebraic and combinatorial objects subject of this research are relevant and appear in many areas of physics and computation. So, we expect that some of the results obtained during this project could shed light on problems in other areas where they appear.

Project coordinators

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AREPTHEO

Aspects of representation theory of Lie algebras and finite dimensional algebras

The project is built around two main areas in Representation Theory: algebraic Lie Theory, with an emphasis on representations of finite and infinite dimensional Lie algebras and their associated quantum analogs; representations of finite dimensional algebras, with a focus on cohomological methods. The main mathematical goals are the following.

Algebraic Lie Theory

– Construction of bases of quantum shuffle algebras at roots of unity using Lyndon words and application to the study of Rosso's realization of Lusztig's positive quantum divided power algebra inside the quantum shuffle algebra.

– Use the description, by Fang and Rosso, of the quantum groups associated to symmetrizable Kac-Moody algebras as quantum quasi-symmetric algebras to provide a new, elementary construction of Lusztig's automorphisms.

– Construction of Gelfand-Tsetlin bases for simple modules of quiver Hecke algebras and applications to the study of some distinguished Gelfand-Tsetlin modules for the Lie algebra gl(n,C).

– Study of cuspidal weight modules for sl(n+1) in the case where the central character is integral to provide a more explicit description.

– Use quantum Weyl algebras (of finite rank) to obtain new families of irreducible representations of quantum groups through the recently constructed morphism from a type A quantum group to a quantum Weyl algebra. Extend this approach to affine Kac-Moody algebras starting with infinite rank quantum Weyl algebras.

– Introduce an adequate notion of representation for the loop of formal diffeomorphisms, defined by Frabetti and Shestakov, and study these representations. Investigate the Sabinin algebra of this loop.

Finite dimensional algebras

– Describe the Lie algebra structure of the degree one component of the cohomology algebra of the exterior algebra and the Gerstenhaber structure of the whole cohomology algebra. Extend this program to the cohomology algebra of the Koszul dual of any quadratic Koszul algebra. To these aims, the use of certain resolutions introduced by Chouhy and Solotar should be adequate tools.

– Describe a basis of the cohomology algebra of monomial algebras and use it to describe its Gerstenhaber structure.

– Study Han's conjecture in the context of 'recollements': if A is an algebra and e an idempotent of A, is it true that Han's conjecture holds for A if and only if it does for A/AeA and eAe ?

– Investigate classes of Artin algebras generalizing Igusa-Todorov algebras and satisfying the finitistic conjecture.

Project coordinators

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DGT
Dynamical Group Theory

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This project is about group actions on low-dimensional manifolds. This is a subject of intense development nowadays and its aim is to find relations between the algebraic or geometric data of a given group (or class of groups) with the dynamical features that an action of this group (or class of groups) can possibly display.

We will focus in two types of problems:

- Realization problems: Given a manifold, what are the groups that can act on it?
- Dynamical quality problem: Given an action of a group, how smooth can this action be
made? Can we characterize the dynamics of group actions when a representation exists?

Project coordinators

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NoLoCE

Nonlocal and Local Coupled Equations: Analysis, Computation, and Probability

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The design of accurate mathematical models and the development of efficient numerical
algorithms for their resolution are topics of paramount importance in applied mathematics and engineering. Good models capture the underlying mechanisms, and their inspection may lead to new questions in pure mathematics.

In this project, we propose to study problems involving systems of coupled partial differential and integro-differential equations. Our research concerns the modeling, analysis, and simulation of such problems. We deal with questions related to materials science, such as the study of interface models in elasticity and electromagnetism and the development of novel formulations in nanophotonics. We propose to study approaches to coupled systems through game theory. Furthermore, we aim to compare local and nonlocal diffusion either in a mixing environment and through the analysis of population dispersal. External optimal control is a salient feature of nonlocal formulations that we propose to analyze. Motivated by their application in the modelling of the respiratory system, we shall also study problems on fractal and random infinite trees.

Project coordinators

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NOTION

NOn-local conservaTION laws for engineering, biological and epidemiological applications: theoretical and numerical

MATH AmSud

Conservation laws with flux function depending on integral evaluations of the conserved quantities arise in several models describing engineering, biological and epidemiological applications. The presence of non-local terms makes the classical techniques developed for hyperbolic systems of conservation laws inapplicable as such, thus requiring the development of novel analytical and numerical tools. Moreover, the presence of integral terms has a huge impact on the cost of numerical simulations, motivating the design of efficient approximation schemes. This project aims to tackle the above mentioned analytical and numerical challenges, focusing on engineering applications (sedimentation, traffic, population dynamics, etc) and biological and epidemiological phenomenon.

Project coordinators

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PLANNING

PLANarity and distaNces IN Graph theory

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Our project aims at investigating four important questions of metric or topological nature in graph theory. The first question is related to a classical result which follows from the Sylvester-Gallai theorem: every non-collinear set of n points in the Euclidean plane determines at least n lines. The notion of "betweenness" allows the notion of line to be extended to every metric space, and it has been conjectured, by Chen and Chvátal, that this result can be extended as well to every metric space. This conjecture is open for metric spaces induced by general graphs, and we aim at developing tools towards solving it by studying particular classes of graphs. The second question is related to the study of vertex colorings with conditions on distance. We will consider colorings which require different colors for vertices at distance (exactly) p, for some fixed p. Considering such a coloring for a graph G amounts to considering a proper coloring of the exact distance graph of G, which has the same vertex set as G and an edge between x and y if and only if these vertices are at distance p in G. For that type of colouring, the answer to the question "how many colours suffice?", can depend greatly on the parity of p. In particular, a finite number of colors suffice if p is odd and we consider planar graphs. We aim at tackling different open problems related to this type of colorings, particularly on planar graphs. The study of cliques in exact distance graphs also interests us as it is surprisingly related to the existence of finite projective geometries. The third deals with the following decision problem: Given a positive integer k and a planar graph G, is the k × k grid a minor of G? We aim to determine whether this decision problem is NP-complete. Since the Grid-Minor Theorem of Robertson and Seymour, roughly states that graphs of large tree-width necessarily contain large grid minors, this problem is related to a central problem on planar graphs: can we effectively compute the tree-width of a planar graph? We hope that our investigations can bring light to this important question as well. Finally, the fourth problem is about dominating sets in planar graphs. In particular, we try to attack the following conjecture, attributed to Matheson and Tarjan: there is a dominating set with at most n/4 vertices in any planar triangulation on n vertices. This conjecture has been settled for planar triangulations of maximum degree 6; and there are related results for hamiltonian planar triangulations and outerplanar graphs. The best-known upper bound for the general case is 17n/53. We are interested in obtaining new upper bounds for the size of a dominating set in planar triangulations or subclasses of them.

Project coordinators

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SCD
Statistics for complex data

The aim of this project is to develop theoretical and computational tools to solve statistical problems that occur when the data lives in high dimensional spaces, are correlated and/or lives in complex spaces that induce complex geometry. The main topics under concern will be regression and classification for (spatial and temporal) correlated data, aggregation, set estimation, dimension reduction, deph notions and ordinary differential equations. In that view, the different skills of the four institutions of the project will be gathered to create a relevant pool of competences and an efficient and fruitful synergy.

Project coordinators

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VOS (Volterra - Switching)

Existence and uniqueness, Numerical approximation, Stability and Applications in population dynamics using Stochastic Volterra Differential Equations with Switching

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In this proposal, we propose to work on four main topics. The first one consists of studying the existence and uniqueness of the solution of a class of stochastic differential equations driven by Brownian motion of the integro Volterra Markov Switching type. The second part of the proposal is to deal with the development of a numerical approximation of the exact solution of a class of Volterra Markov Switching differential equations. In particular, we are interested in the study of the rate of convergence of the Euler, θ-Euler and Milstein scheme for some special type of stochastic integro Volterra with Markov Switching. The third part is concerned with the study of the stability with respect to the initial condition (trivial solution) for a special class of stochastic differential equations, driven by Brownian motion and an independent Markov switching. We plan to study theorems for the pth-moment exponential stability for the solution of these equations. Finally, in the last part of this proposal we consider Volterra stochastic equations with switching for the population dynamics modelling. We study the existence of the solutions to a specific Volterra equation and its stability and persistence in the mean value. In addition, we construct a specific modelling and simulation study of the population dynamics of the stochastic epidemics with Markovian switching.

Project coordinators

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