# Proyectos MATH AmSud - convocatoria 2017

## FLaNASAGraTA - Franco-Latin Network on Algebraic, Spectral, and Algorithmic Graph Theory and its Applications

Abstract

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| The present project proposes the establishment of a network of collaboration among Argentina, |
| Brazil and France, using the strength of 3 mathematics groups of 3 different institutions. The research topic of the proposal is Algebraic Graph Theory, an important and modern area of discrete mathematics. The proposal is structured in such a way that the training of highly qualified human resources and research activities are intertwined, this will ensure the generation of new knowledge in a relevant scientific area and leave permanent ties of collaboration between the different research groups beyond the completion of the project. |

Institutions and scientific coordinators:

Vilmar Trevisan Instituto de Matemática e Estatística, Universidade Federal do Rio Grande do Sul, BRASIL

Daniel Alejandro Jaume, Universidad Nacional de San Luis, ARGENTINA

Jorge Ramírez-Alfonsín, Institut Montpelliérain Alexander Grothendieck, Université de Montpellier II, FRANCIA

HidiParHodyn - Higher dimensional and parabolic holomorphic dynamics

Abstract

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| We will organize a workshop and a mini course and stimulate existing collaborations and new ones on the topics above mentionated. We will particularly stimulate interaction among students, young researchers and the France-Amsud community of the area. |

Institutions and scientific coordinators:

Jasmin Raissy, Institut de Mathématiques de Toulouse, FRANCIA

Matthieu Arfeux, Instituto de Matemáticas, Pontificia Universidad Católica de Valparaíso (PUCV), CHILE

Sylvain BONNOT, Instituto de Matemática e Estatística da Universidade de São Paulo, BRASIL

## LCC - Logic, Complexity and Categories

Abstract

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| We use category theory as a vehicle in order to extract logical as well as homotopical information out of more low-level structures capturing computability. Realizability in the original sense ascribes meaning to logical sentences by providing sets of witnessing codes of computational entities like Turing machines, lambda terms or combinators. It turned out that the relevant information can be conveniently organised in categories, mostly (but not only) in *topoi* starting with Hyland’s *Realizablity Topos* and elaborations upon based on arbitrary *Partial Combinatory Algebras*. This material is for the most part well-known by now, yet much less so is its connection to *Homotopical Type Theory*, recently discovered by Worytkiewicz with Van Oosten’s work as starting point. We intend to further explore this topic. The topoi just mentionned capture *intuitionistic realizability*. The *classical* counterpart of the latter, developped by Krivine and others, follows a similar thread of ideas yet relies on a more sophisticated notion of underlying computation. It has been taken to the realm of topoi by Streicher, based on an ordered version of partial combinatory algebras. Streicher’s series of papers is by no means a simple affair. It has recently been improved by Ferrer, Frey, Guillermo and Miquel by means of a systematic usage of Miquel’s *implicative algebras*, leading to the construction of the *Implicative Tripos*. Although it is standard knowledge how to construct a topos from a tripos, this specific instance is far from being well-studied yet. We intend to improve this state of affairs, in particular in order to extract categorical models of the *Zermelo-Fraenkel set theory*, and also to explore a potential link to Homotopy Type Theory. Some attempts to study Computational Complexity have been made based on different categorical structures such as cartesian categories, cartesian closed categories and topoi. However, there is a more specific approach based on Cockett’s Turing Categories and further studied by Cockett, Diaz-Boils, Gallagher and Hrubes which seems well suited for studying complexity-related topics in a categorical framework. For unlike what happens with realizability topoi, the theory of Turing categories is more *structural* in the sense that there is no underlying explicit computational machinery. At the same time, and this really is the common theme linking the different parts of this project, the study of Turing categories is equivalent to the study of partial combinatory algebras underlying intuitionistic realizability topoi. We intend to investigate how far this circle of ideas carries over to the classical setting based on implicative algebras. Turing categories are by construction quite convenient for the study of the computational mechanism itself, so in particular for the study of the corresponding classes of complexity. As a speculative item, we intend to investigate the possibility of (co)homology-style invariants detecting these complexity classes.  Institutions and scientific coordinators:  Alexandre Miquel, Universidad de la República, URUGUAY  Joaquín Díaz Boils, Pontificia Universidad Católica del Ecuador, ECUADOR  Krzysztof Worytkiewicz, Université Savoie-Mont Blanc, FRANCIA |
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## MATH-GEO - MATHematical methods for GEOphysical flows

Abstract

Nonlinear processes, such as advection and turbulent mixing, play a central role in geophysical sciences. The theory of nonlinear dynamical systems provides a systematic way to study these phenomena. Its stochastic extension also forms the basis of modern data analysis techniques, predictability studies and data assimilation methods. Contributions in the field of Topology and Dynamics of Chaos include methods conceived to unveil the structure organizing flows in phase space, building the gap between data and low-dimensional modeling. Low-order models in climate dynamics are highly desirable, since they can provide solutions in cases where high-resolution numerical simulations cannot be implemented, as in short-term wind forecasting. At the same time, the procedure provides a tool-kit for model validation, emulation or inter-model comparison, with interesting prospects in all fields of oceanographic and atmospheric sciences, including climate detection and attribution. The strategy constitutes an unprecedented and promising perspective, offering an original approach to the subject, with mathematical concepts that are not necessarily widespread in the geophysics scientific community. This proposal gathers specialists with a know-how in the most challenging aspects of the focused research field: coherent structure detection in fluid flows for the exploration and interactive visualization of scientific data (LIMSI France), data assimilation and fluid motion analysis from image sequences (INRIA Rennes), numerical models and data assimilation (CMM-Chile) stochastic models for climate dynamics with application to El Niño Ocean models (USIL-Peru), mathematical methods for weather and climate (CIMA-UBA & IMIT / IFAECI, Argentina), geophysical flows and dynamical systems (LMD France), mixing structures and Lagrangian analysis of multisatellite data (LOCEAN France), marine and estuarine hydrodynamic and water properties numerical models (INCO & IMFIA-Uruguay), in situ measurements of oceanographic conditions (CEBC France, in program with CNES France and CONAE Argentina), global modelling technique and topological characterization of flows (CORIA with CESBIO, France).

Institutions and scientific coordinators:

Juan Ruiz, CIMA (Centro de investigaciones del mar y de la Atmósfera), Universidad de Buenos Aires, ARGENTINA

Mónica Fossati, IMFIA: Instituto de Mecánica de los Fluidos e Ingeniería Ambiental, INCO: Instituto de

Computación, Facultad de Ingeniería - Universidad de la República, URUGUAY

Alejandro Paredes, USIL: Universidad San Ignacio de Loyola, PERU

Axel Osses, CMM: Center for Mathematical Modeling, CHILE

Denisse Sciamarella, LIMSI: Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur, FRANCIA

## MOVECO - Modeling, Optimization and Viability for Epidemics Control

Abstract

Communicable and infectious diseases constitute one of the leading causes of illness and death throughout the world. The diversity of infection agents (viruses, bacteria, microbes, etc.) combined with their ability to evolve and adapt to changing host populations, environments, practices, and technologies creates ongoing threats to human health and appeals for more sophisticated policies for disease prevention and control. This project combines the experience and skills of economists, statisticians, medical doctors, healthcare managers, applied mathematicians, and control scientists to propose meaningful mathematical models and to develop new methods (based on optimization and viability approaches) for control of communicable and infectious diseases. The mathematical study of three central topics (T1, T2, and T3) is the core of this project. However, the practical outcome of this project should be beyond mathematics. Namely, we propose new techniques to identify the sustainable objectives for the control of communicable or infectious diseases and to find a balance between the intervention costs and expected benefits (in the form of future averted infections), which completely agrees with the cost-effectiveness approach commonly used in healthcare management.

Institutions and scientific coordinators:

Olga VASILIEVA, Universidad del Valle, COLOMBIA

Lilian Sofia SEPULVEDA SALCEDO, Universidad Autonoma de Occidente (UAO), COLOMBIA

Pablo AGUIRRE, Center for Analysis and Mathematical Modeling Valparaíso (AM2V), Universidad Técnica Federico Santa María (UTFSM), CHILE

Héctor RAMÍREZ, Center for Mathematical Modeling (CMM), Universidad de Chile, CHILE

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## PHOTOM - PHOTOvoltaic solar devices in Multiscale computational simulations

Abstract

The work consists of devising, analyzing and implementing new multiscale finite element methods, called Multiscale Hybrid-Mixed (MHM) method, for the Helmholtz and the Maxwell equations in the frequency domain. The physical coefficients involved in the models contain highly heterogeneous and/or high contrast features. The goal is to propose numerical algorithms to simulate wave propagation in complex geometries as found in photovoltaic devices, which are naturally prompt to be used in massively parallel computers. We demonstrate the well-posedness and establish the optimal convergence of the MHM methods. Also, the MHM methods are shown to induce a new face-based a posteriori error estimator to drive space adaptivity. An efficient parallel implementation of the new multiscale algorithm assesses theoretical results and is shown to scale on a petaflop parallel computer through academic and realistic two and three-dimensional solar cells problems.

Institutions and scientific coordinators:

Frédéric Valentin, LNCC - National Laboratory for Scientific Computing, BRASIL

Diego Paredes, PUCV- Pontificia Universidad Católica de Valparaíso, CHILE

Rodolfo Araya, UDEC - Universidad de Concepción, CHILE

Stéphane Lanteri, INRIA - Institut National de Recherche en Informatique et en Automatique, FRANCIA

## SaSMoTiDep - Statistical and Stochastic modeling for time-dependent data

Abstract

In many applications, multiple measurements are made on one or several experimental units over a period of time. Such data could be called time-dependent data. From a statistical point of view, if we consider only one experimental unit, we can use a time series analysis. In the other hand, if we consider experimental designs (or observational studies) for several experimental units (or subjects) where each subject is measured at several points in time, we can use the term longitudinal data. In this project, we propose to study several statistical and stochastic models for repeated measures using parametric and non-parametric approaches. In particular, we will study the inference in complex mixed effects models, we will propose novel segmentation models for multiple series, non parametric methods in dependent models and stochastic models. We will apply these methods to real data from several fields as biometrics, reliability, population dynamics and finance.

Institutions and scientific coordinators:

Viswanathan Arunachalam, Universidad Nacional de Colombia, COLOMBIA

Cristian Meza Becerra, Universidad de Valparaíso, CHILE

Marc Lavielle, INRIA Xpop-Ecole Polytechnique, FRANCIA

## GDG - Geometry and Dynamics of Infinite Groups

Abstract

The research projects of all participants are concentrated around the following problems:

1. to study discrete group actions preserving some structures (hyperbolic, affine and others);

2. to study convergence group actions which are the common feature of lattices of rank one symmetric spaces

and more general hyperbolic or relatively hyperbolic actions by homeomorphisms;

3. to study actions of groups of diffeomorphisms of surfaces and affine interval exchange transformations;

4. to study the orbifold quotient spaces of the discontinuous geometric actions, their geometrical and topological

properties.

5. to study singular algebraic sets and morphisms.

Institutions and scientific coordinators:

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