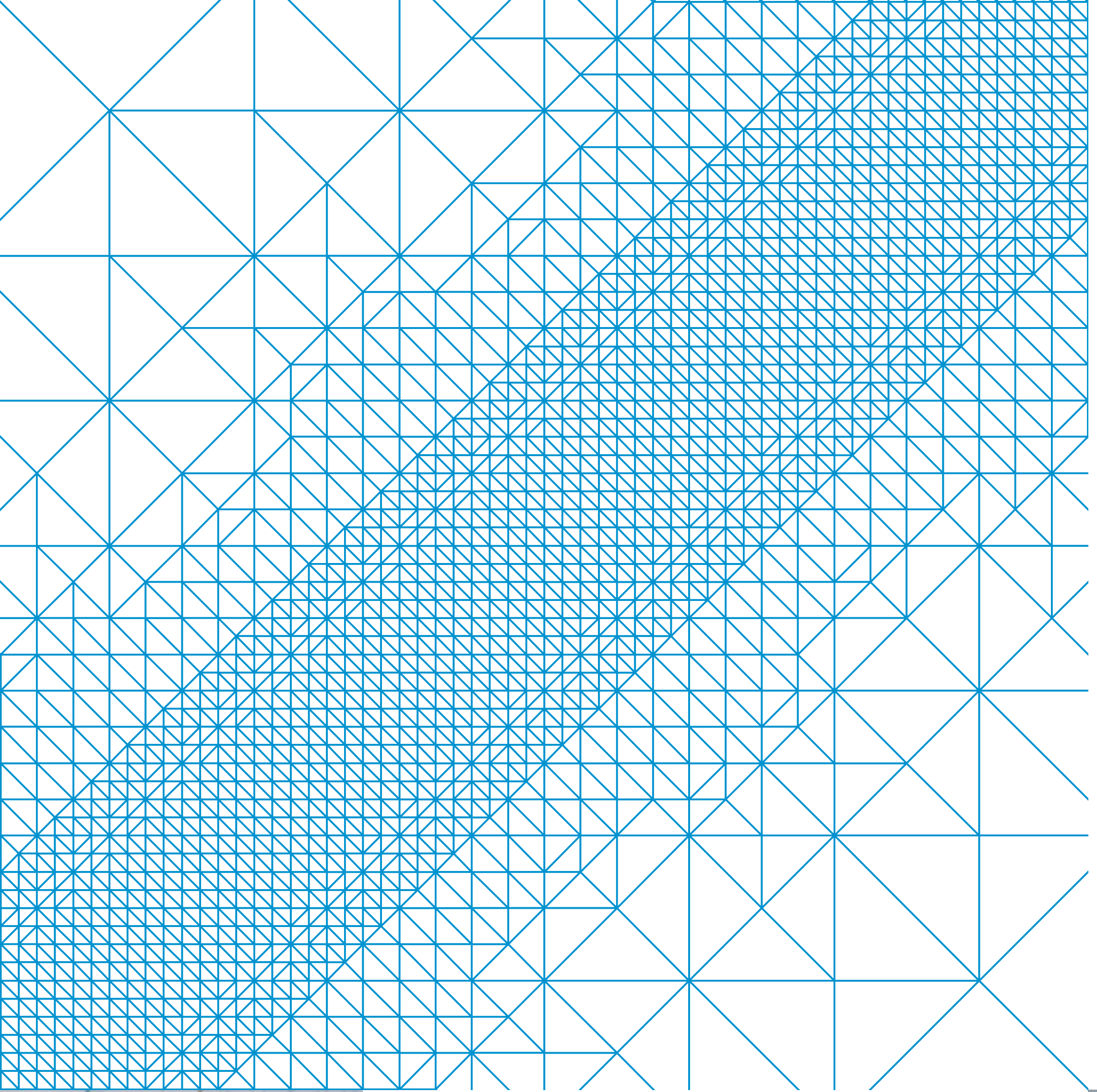
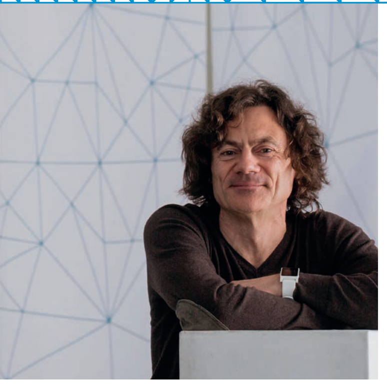


MATHEMATICS THE LANGUAGE OF SCIENCE

(bcam)
basque center for applied mathematics

EXCELENCIA SEVERO OCHOA



JOSE A. LOZANO
Scientific Director

Let's write together the Mathematics of the future

BCAM is a world-class interdisciplinary Research Center in the field of Applied Mathematics that was founded in 2008 as a Basque Excellence Research Center (BERC), with a focus on interdisciplinary research in Mathematics, as well as training and attracting talented scientists, and promoting scientific and technological advances worldwide. The center has been awarded (2013, 2018) twice with the Severo Ochoa distinction that consolidates BCAM as one of the most relevant institutions of the field in Europe.

From the inception of humanity, Mathematics has always been the basis on which all natural and social sciences have been supported. Reciprocally, sciences have been the source of inspiration for most mathematical developments throughout history. In recent decades, technology has joined science in promoting Mathematics, demanding new mathematical developments capable of modelling such technology and predicting its behaviour. Similar to the case of science, this modern Mathematics is resulting in new technological advances. In BCAM, our goal is to be leaders in the discovery of the necessary Mathematics that contribute to a scientific and technological development oriented towards social welfare. That is, our goal is to write together the Mathematics of the future.

01 **CM** — Computational Mathematics

02 **M3A** — Mathematical Modelling with Multidisciplinary Applications

03 **MP** — Mathematical Physics

04 **APDE** — Analysis of Partial Differential Equations

05 **DS** — Data Science & Artificial Intelligence

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PARTICIPATING INSTITUTIONS

Eusko Jaurlaritza – Gobierno Vasco (Hezkuntza, Hizkuntza Politika eta Kultura Saila / Departamento de Educación, Política Lingüística y Cultura)
innobasque – berrikuntzaren euskal agentzia / agencia vasca de la innovación
ikerbasque – Basque Foundation for Science
Universidad del País Vasco – Euskal Herriko Unibertsitatea
Bizkaia – foru aldundia / diputación foral

PUBLIC AND PRIVATE FUNDING

Eusko Jaurlaritza – Gobierno Vasco
Gobierno de España – Ministerio de Economía y Competitividad
Bizkaia – foru aldundia / diputación foral
Fundación BBVA
Bizkaia talent
Obra Social "la Caixa"
Fundación Iberdrola
Bizkaia beaz

SCIENTIFIC TOPICS

01 CM
Computational Mathematics

We develop new computational technologies in order to increase the reliability of computer simulations.

001 **MATHDES** — Mathematical Design, Modelling and Simulations
002 **CFDMS** — CFD Modelling and Simulation
003 **CFDCT** — CFD Computational Technology

OBJECTIVE

To develop new mathematical methods, robust numerical schemes and software to solve complex and large-scale challenging real-life flow problems on massively parallel computers.

DESCRIPTION

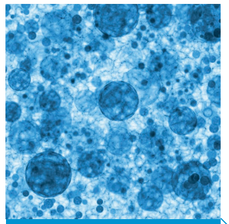
We analyse modern numerical methods such as advanced Finite Element (AFE) and Finite Volume (FV) techniques applied to stationary and time-dependent problems. In addition, we develop new meshless multi-scale methods such as Smoothed Particle Hydrodynamics (SPH) or Dissipative Particle Dynamics (DPD) applied to complex fluids and mesoscopic flow problems.

APPLICATIONS

Characterisation of the Earth's subsurface composition for CO2-sequestration and oil or gas extraction; dynamics of complex particulate fluids, microfluidics, rheology; CFD applied to complex flows that rise in a number of engineering sectors including environmental, chemical/manufacturing, polymer/food processing and biomedicine.

02 M3A
Mathematical modelling with multidisciplinary applications

Life and physical sciences pose mathematical and technological challenges, which if advanced will impact society.



001 **MSLMS** — Modelling and Simulation in Life and Materials Sciences
002 **MTB** — Mathematical Theoretical Biology
003 **MCEN** — Mathematical, Computational and Experimental Neuroscience

OBJECTIVE

Novel theoretical, computational and technological tools to explain complex real-world problems and assist scientists and practitioners.

DESCRIPTION

We push the boundaries of mathematics and develop analytical frameworks, multiscale parsimonious models, advanced algorithms and novel measuring techniques to extract invariant patterns hidden within the multi-spatial-temporal scales involved in biological and physical systems. A closed loop between hypothesis testing, HPC, high throughput data and data management enable quantitative and qualitative knowledge discovery.

APPLICATIONS

Patient-specific simulation; disease outbreak and within-host modeling; multi-strain pathogen interactions; drug resistance; brain computation and neural code; neurodegenerative diseases; metabolism, advanced materials for ion-batteries; geosteering; polymerization and chemical reaction mechanisms.

03 MP
Mathematical Physics

Towards mathematical understanding of theories of Physics.

001 **QM** — Quantum Mechanics
002 **SP** — Statistical Physics
003 **STAG** — Singularity Theory and Algebraic Geometry

OBJECTIVE

At the interface between Mathematics and Physics is the so-called Mathematical Physics that at BCAM is represented by the research lines in Quantum Mechanics, Statistical Physics and Singularity Theory & Algebraic Geometry.

DESCRIPTION

We study several questions of classical physics that although long known, are still not understood from the mathematical perspective, microscopic origin of macroscopic laws (like in electricity) and natural phenomena of front motion embedded into random environments. More theoretically, we study the geometry of Singularities appearing in Algebraic Geometry.

APPLICATIONS

Our methods could apply to, future applications of quantum technologies or forecast of wildland fire propagation to preserve natural heritage, cryptography and string theory.

04 APDE
Analysis of Partial Differential Equations

Describing efficiently real life phenomena using PDE models.

001 **WAVE** — Linear and non-linear Waves
002 **HA** — Harmonic Analysis and Inverse Problems
003 **APAN** — Applied Analysis

OBJECTIVE

We explore and exploit the deep connections between Partial Differential Equations, Harmonic Analysis, and Applied Mathematics so as to describe the most diverse phenomena.

DESCRIPTION

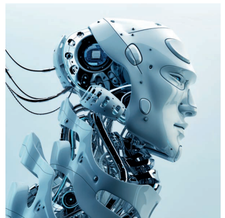
The attempt to efficiently describe real-life phenomena leads to mathematical models, often expressed in terms of PDEs, capturing the essential features of the phenomena. Solving these equations implies the use and development of sophisticated techniques of analysis together with the realisation of numerical simulations to eventually determine the validity of the models.

APPLICATIONS

The understanding of the fundamental principles that control relevant phenomena in physics and biology could eventually become of use for scientists working on those fields. We also expect to apply the efficient algorithms developed by our numerical simulations in real life problems.

05 DS
Data Science & Artificial Intelligence

A huge amount of knowledge is hidden in the data, waiting to be extracted and exploited.



001 **CO** — Combinatorial Optimization
002 **AS** — Applied Statistics
003 **ML** — Machine Learning

OBJECTIVE

To develop new statistical, machine learning and optimisation methods that can extract knowledge from the large amount of data generated nowadays.

DESCRIPTION

In the applied statistics field, the main topics of our research are semi-parametric regression, multidimensional smoothing, (Bayesian) hierarchical models, computational statistics... Regarding Machine learning, we work on supervised and unsupervised classification of massive data, probabilistic graphical models, time series, Bayesian optimisation, etc. In optimisation we pursue the developments of efficient metaheuristics methods.

APPLICATIONS

Massive data and optimisation problems from financial to social media, marketing, medical domains (diagnosis and prognosis), genetics, environmental modelling, demography and biostatistics, logistics, scheduling and planning.

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