“If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is”

—von Neumann, 1947
TABLE OF CONTENTS

Research Areas 01
People 02
Scientific Output 03
Programmes 04
Collaborators 05
Funding 06
Dissemination 07
• **Objective:** To develop new mathematical methods, robust numerical schemes and software to solve complex and large-scale challenging real-life 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.
**Objective:** Development of novel theoretical and computational tools for efficient and detailed simulation of multi-scale complex systems describing real life problems in biology, medicine, public health and society.

**Description:** Improved algorithms, efficient sampling techniques, advanced models combined with observational data ensure a full exploitation of the capabilities of modern HPC in tackling the mathematical challenge of strong coupling across scales, adaptive and emergent dynamics. Pushing the boundaries of mathematics and interdisciplinary knowledge helps to reveal hidden structures of the complex systems.

**Applications:** Patient-specific simulation (cardiovascular, brain, cancer), neurodegenerative diseases, drug design, self-assembly in bio-chemical processes, energy materials modelling and uncertainty quantification. Targeted at biologists, clinicians and industries.
● **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.
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.
• **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.
108 people

+22 more than in 2018

1 Scientific Director

23 Research line leaders and BCAM researchers

39 Postdoctoral fellows

9 Administration Staff Members

10 KTU Research Technicians

22 External Scientific Members
BCAM received the HR Excellence in Research Award in 2016. This recognition by the European Commission identifies the universities and institutions that generate and support the existence of a stimulating and favourable environment for research work by adapting their human resources policies to the 40 principles of the European Charter & Code for Researchers.

In May 2019 assessors from the European Commission concluded that the implementation of the Action Plan at BCAM was progressing appropriately and the center successfully passed the first Internal Review of the HR Excellence in Research Award.

HIGHLIGHTS OF THE HRS4R ACTION PLAN:

- Yearly Training and Development plan (technical and non-technical)
- Implementation and monitoring of the Gender Equality Plan
- New offices to provide more space for researchers within the Bizkaia Science and Technology Park (Leioa)
- Organization of leisure and team building activities
- Creation of the BCAM Management Committee to evaluate the distribution of funding for BCAM programs and personnel per area and the performance evaluation of researchers.
- Elaboration of a Work-Life Balance document for employees
- Dissemination of the Career Development Plan
HIGHLIGHTS OF THE GENDER EQUALITY PLAN:

- Constitution of the **Equality Commission**
- Annual **training in Gender Equality** for all staff members to promote employee awareness in this area.
- Partnership agreement with the **Women for Africa Foundation (FMxA)** to host an African woman researcher for 6 months.
- Twitter contest to name the Seminar Room at BCAM after a woman mathematician, which is now the **“Maryam Mirzakhani Seminar room”**
- Support in the creation of **R-ladies Bilbao**, a group promoting diversity in the R community via meetups, mentorship & global collaboration
Rheology of non-colloidal suspensions based on the dynamics of lubrication forces

1. Non-Colloidal suspension in Newtonian fluid (1D and 2D lubrication forces considered)

The dynamics model is obtained considering both the particle motion of lubrication forces as given in the following:

\[ \tau(y) = f(y) \left( \frac{\partial \sigma}{\partial y} \right)_\perp \]  

In the above:

\[ f(y) = \begin{cases} 
1 \quad &\text{for } y < y_c \ \text{and } \sigma > 0 \\
\sigma_{\text{max}} \quad &\text{for } y > y_c \ \text{and } \sigma > 0 \\
0 \quad &\text{for } y < y_c \ \text{and } \sigma < 0 \\
\sigma_{\text{max}} \quad &\text{for } y > y_c \ \text{and } \sigma < 0 
\end{cases} \]

Definition of \( y_c \):

\[ y_c = \frac{\max(f(y))}{f(y)} \]

1.1 Simulation settings

- \( n_{\text{max}} = 10^6 \):
  - \( \eta = 0.01 \), \( \chi = 0.001 \), \( N = 0.005 \), \( \Delta t = 0.00005 \), \( \text{num. steps} = 500 \)

- \( \text{dim} = 3 \), \( L = 0.02 \), \( H = 0.02 \), \( \text{num. steps} = 5 \), \( \Delta t = 0.0005 \), \( \text{num. steps} = 500 \)

- \( \text{B} = 1 \), \( \text{num. steps} = 100 \), \( \text{num. steps} = 2 \), \( \text{num. steps} = 1 \), \( \text{num. steps} = 100 \), \( \text{num. steps} = 500 \)

- \( \text{num. steps} = 5 \)
SCIENTIFIC PUBLICATIONS

191
PUBLICATIONS
INDEXED

83,2%
articles
in D1

41,9%
articles
in Q1

BCAM H-INDEX
33
1st DECILE JOURNALS

- ACS Applied Materials and Interfaces
- ACS Macro Letters
- ACS Synthetic Biology
- Acta Materialia
- Annali di Matematica Pura ed Applicata
- Archive for Rational Mechanics and Analysis
- Astrophysical Journal
- Bernoulli
- Calculus of Variations and Partial Differential Equations
- Communications in Partial Differential Equations
- Computer Methods in Applied Mechanics and Engineering
- Environmental Modelling and Software
- Geoscientific Model Development
- Information Fusion
- Information Sciences
- International Journal for Numerical Methods in Engineering
- International Journal of COPD
- International Mathematics Research Notices
- Journal des Mathematiques Pures et Appliquees
- Journal of Computational Physics
- Journal of Differential Equations
- Journal of Fluid Mechanics
- Journal of Functional Analysis
- Journal of Geometric Analysis
- Journal of Hydrology
- Journal of Medical Internet Research
- Journal of Proteome Research
- Macromolecules
- Mathematische Annalen
- Metabolic Engineering
- Nature Communications
- Nature Reviews Microbiology
- New Journal of Physics Nonlinearity
- Physical Review B
- Proceedings of the IEEE
- R Journal
- Renewable and Sustainable Energy Reviews
- Scientific Reports
- Selecta Mathematica, New Series
- SIAM Journal on Mathematical Analysis
- SIAM Journal on Numerical Analysis
- Sociological Methods and Research
- Statistics and Computing
- Transactions of the American Mathematical Society
- Transportation Research Part C: Emerging Technologies
M A S T E R & PH D T H E S I S

27
ONGOING PHD STUDENTS IN 2019

+11
NEW PHD STUDENTS

THESIS DEFENDED IN 2019
13

5
MASTER THESIS DEFENDED IN 2019
TIME 32. NONEXISTENCE OF EXTREMIZERS ON THE HYPERBOLOID

Theorem: The best constant for $f^{(n)}(x) = x^n$ is $\lambda_n = \frac{n!}{(n-1)!}$.

Examples:
- $\lambda_2 = \frac{2!}{1!} = 2$
- $\lambda_3 = \frac{3!}{2!} = 3$

Foschi's Argument

Constants:
- $C_1 = \frac{1}{\sqrt{2\pi}}$
- $C_2 = \frac{1}{\sqrt{2\pi}}$

Programmes

- 04
- PROGRAMMES
PARTICIPANTS IN OUR PROGRAMMES

19 Visiting fellows

26 Interns

174 Visitors
COLLABORATORS IN THE FRAMEWORK OF THE BASQUE SCIENCE, TECHNOLOGY & INNOVATION NETWORK
NEW INTERNATIONAL AGREEMENTS

ISAAC NEWTON INSTITUTE FOR MATHEMATICAL SCIENCES
ICARUS DIGITAL MATH
ILLY CAFFE
THE UNIVERSITY OF CALIFORNIA - UCLA
TSINGUA UNIVERSITY
Let's write together Mathematics for the Future
Idatz ditzagun elkarrekin etorkizuneko matematikak
Escribamos juntos las matemáticas del futuro

\[ f(x,t;x) = \int_0^{\infty} G(x-x_{\hat{a}}l, l, t) q(l,t) \, dl, \quad \hat{a}, \hat{m} \geq 0 \]

\[ g(x-x_{\hat{a}}l, l, t) = \begin{cases} G(x-x_{\hat{a}}l, l, t), & \text{otherwise} \\ G(x-x_{\hat{a}}l, l, t) \end{cases} \]

\[ C(x-x_{\hat{a}}l, l, t) = \exp \left( -\frac{(x-x_{\hat{a}}l)^2 + (y-y_{\hat{a}}l)^2}{2} \right) \]
GENERAL DISSEMINATION ACTIVITIES

PUBLIC DISSEMINATION
Bidebarrieta talks on Mathematics in everyday life, Pint of Science, BCAM-Naukas Pi Day, Bilbao Art District...

PROMOTION OF SCIENTIFIC VOCATIONS
Aupatuz, Talentia, First Lego League Euskadi...

PRESS & OTHER MEDIA
La mecánica del Caracol (Radio Euskadi), Zientzia Kaiera, Mapping Ignorance...

SOCIAL NETWORKS
Follow BCAM on Twitter (@BCAMBilbao), Linkedin and Youtube
What is the Basque Center for Applied Mathematics?
39 seminars
BCAM Scientific Seminars & Working groups

9 workshops
QBIO, BIDAS, FCPNLO...

17 courses
UPV/EHU Joint courses & BCAM Courses
BCAM played an active role in the last edition of the International Congress on Industrial and Applied Mathematics that took place in Valencia from 15-19 July:

• The center had an academic exhibitor
• A video about the center was broadcasted on ICIAMTV
• 18 BCAM researchers participated as speakers at ICIAM minisymposia