CEMS.UL
Faculdade de Ciências
Universidade de Lisboa

External funding for Fundamental & Applied Research

CEMS.UL : Center for Mathematical Studies of the University of Lisbon

Date : 27/06/2025
Reference person at CEMS.UL : Nicolas Van Goethem - 930416751 - vangoeth@fc.ul.pt

Summary

1 Definition of the project & its contribution to the public good **2**
1.1 Current difficulties & opportunities for scientific research in Portugal 2
1.2 Corporate Scientific Responsability 3

2 Definition of the target audience & Scientific projects. **4**

3 Managing entities **5**
3.1 The Research Center : CEMS.UL 5
3.2 The private entity managing the funds : FCiências.Id 6

4 Scientific projects **7**
4.1 A novel model of elastoplasticity 7
4.2 Analysis of time series data via topological data analysis 8
4.3 Mathematics for Forest Protection and Sustainability : Optimizing Access for Firefighters 9
4.4 Extracting Quantitative Knowledge from Proofs : Logical Tools for Reliable Computation and Optimization 10

Appendix **12**
4.5 Annex 1 12
4.6 Annex 2 12

Part 1
Definition of the project & its contribution to the public good

1.1 Current difficulties & opportunities for scientific research in Portugal

Scientific research in Portugal experienced growth from the mid-2000s until the financial crisis of 2010 and the Troika's austerity measures, which led to a brain drain—most of whom have not returned to the country. From the mid-2010s onwards, the growth phase resumed, notably with a new wave of academic recruitment and a series of FCT (Fundação para a Ciência e a Tecnologia) pograms aimed at attracting top international researchers (the iFCT, then CEEC, and finally FCT tenure programmes).

This growth now appears to be stalling, and the most recent round of research center funding (2025–2029) has shown a drastic reduction in public funding (by about 40% for a large majority of centers), making their functioning extremely difficult and seriously compromising the continuation of scientific projects and goals in the short, medium, and long term. For instance, as for our center, we improved all parameters of the FCT evaluation with respect to 5 years ago, but get cerca 50% of our previous funding. This, despite being our center, nationwise, one with the highest success rate in many FCT programmes.

It is increasingly important to define and develop partnerships with private-sector companies, as public funding is steadily declining due to current economic conditions, unsteady definiton of priorities by the Governments, with the State deeming research and innovation issues, as well as academic formation, as non-priorities. It is essential to build this socio-economic fabric, as our companies benefit from staff trained at rigor and excellence. On the other hand, academic researchers gain from the expertise of companies in proposing research topics. Finally, higher education itself can also benefit from both approaches, which are highly complementary.

This proposal aims to describe four projects that are strategic for our center, but currently lack public funding and critical mass, to fully achieve their scientific goals. All projects include the following aspects :

— Achieving scientific goals
— Publish results in high-level scientific journals with international peer review
— Funding researchers at all levels through contract or fellowships
— Presentation of the results to the specialized audience, and when possible to the general public.

The average duration of one project is 18 months.

The funding of PhD must be for at least 3 years, being the average duration of a PhD thesis 4 years. Without this condition the researcher may be short of funding in the middle of her/his studies.

Of course, in case the company/single person or entity is funding a specific project or a specific PhD student, the related funding origin will be mentioned on each presentation and publication.

A detailed value of each cost line will also be given.

1.2 Corporate Scientific Responsability

Contributing to Portuguese research is an investment in the country's intellectual future. It is well known that today's major innovations often stem from fundamental research funded decades ago. Reputed long-established companies in R&D and startups that succeed in the long term are those that also give back to society. This is an investment in the collective future, not a cost. It also resonates with Portuguese cultural values of solidarity and education, emphasizing the importance of knowledge and its transmission.

By investing in scientific research, means for your company a high-level societal engagement that serves as a means of attractiveness and reputation, as well as a lever of influence within the scientific and political ecosystems.

By supporting Portuguese researchers or laboratories, your company demonstrates its commitment to the national scientific development ; this aligns well with Portugal's discourse on innovation and knowledge promoted by the current government.

By supporting fundamental research, you demonstrate that your company values knowledge, not just profitability. This is a meaningful distinction in an ecosystem where most players are focused on the short term. Moreover, it sends a strong signal to institutional investors and impact funds. Additionally, it can be leveraged in communications—through press relations, awards, and certifications. Because investing in Portuguese talent is also part of your mission and strategy.

Part 2
Definition of the target audience & Scientific projects.

Scientific research is an activity that begins as early as the undergraduate level (through introductory internships), continues during the Master's degree (involving substantial work, which may be original and, in the best cases, lead to a publication), and then extends to the PhD (at this level an original work is required) and postdoctoral level (researchers who hold a PhD but do not yet have a permanent position, usually with some experience and autonomy in their research).

Typically, the cost of a fellowship is as follows :

— BII fellowship (bolsa de Iniciação à Investigação - undergraduate level) : €651,12/month

— BI fellowship (bolsa de Investigação - master level) : €1.259,64/month

— doctoral fellowship (bolsa de doutoramento - graduate level) : €1.309,64/month

— post-doctoral fellowship (bolsa de pós doutoramento - research level) : €1.851,00/month.

No funding will be used for material (computer etc.), but only for funding persons achieving a particular research with precise objectives and timeline. Funding of contracts, fellowships, and conference attendance will be elligible (such as registration fees, travel, and accommodation).

The researchers will achieve their work at the University of Lisbon.

As for the Scientific projects, we propose 4 projects illustrating at the same time the variety of the approaches and of the applications, and the power of the theoreticak tools used. They read as follows :

1. **Mathematical modelling in Mechanics** A novel model of Elasto-plasticity (theory & numerical simulations).
2. **Geometric & Topological modelling** Analysis of time series data via topological data analysis.
   — *applications : Machine Learning & AI, Robotics, Anomaly Detection & Fault Diagnosis, Neuroscience & Cognitive Science, Audio, Speech & Signal Processing, Biomedical & Physiological Signals, Earth & Environmental Systems, Finance & Econometrics*
3. **Modelling & Optimization** Mathematics for Forest Protection and Sustainability : Optimizing Access for Firefighters
4. **Logics & Proof theory** Extracting Quantitative Knowledge from Proofs : Logical Tools for Reliable Computation and Optimization
   — *applications : Reliable Computation, Verified Optimization, Provable ML/AI, Safety-Critical Control, Explainable AI, Resource bounds.*

Part 3
Managing entities

3.1 The Research Center : CEMS.UL

CEMSUL (formerly CMAFcIO) develops research in several areas of Mathematical Sciences, ranging from Foundations to Applications. It was founded more than 40 years ago, and is one of the oldest center still in activity, in Mathematical Science, in Portugal. In particular this research center has over the years supervised a significant amount of PhD students in Portugal, which are now senior researchers and professors in the Academia. Its main objectives are :

— to advance knowledge in Mathematics ;

— to promote research of top quality at the international level and engage in international collaborations ;

— to pursue and reinforce our historical role in the training of the best young mathematician researchers in Portugal ;

— to foster and develop applications to relevant problems in the Sciences and in Industry ;

— to participate in high level outreach activities for the communication of Mathematics in schools and for the wider public.

The main research groups of CEMS.UL are :

— Differential Equations and Nonlinear Analysis ;

— Mathematical Logic ;

— Differential and Algebraic Geometry ;

— Mathematical Physics ;

— Linear Algebra ; Representation Theory and Combinatorics ;

— Operations Research and Optimization.

3.2 The private entity managing the funds : FCiências.Id

FCiências.ID – Associação para a Investigação e Desenvolvimento de Ciências, is a non-profit private association, endowed with legal personality and with the public utility statute. It was created in january 9, 2017, as a common initiative of 7 organizations. Its associates are (or have been) :

Faculdade de Ciências da Universidade de Lisboa Maxdata Software, S.A. ESRI Portugal - Sistemas e Informação Geográfica, S.A. SAPEC PORTUGAL - SGPS, SA SGS PORTUGAL – Sociedade Geral de Superintendência, S.A. Closer Consulting (since 8-3-2019) Crowe Portugal Lda. (since 13-12-2024) SAER - Sociedade de Avaliação Estratégica e Risco Lda. (until 13-12-2024) StartFactor, Statistical Consulting and Training (until 31-12-2018)

FCiências.ID envisages to develop, support and potentiate R&D and innovation activities of its associates, therefore creating a more challenging environment for research and innovation.

FCiências.ID is the legal representative of 20 research centres, in the fields of Mathematics, Statistics and Operational Research, Physics, Space and Astrophysics, Chemistry and Biochemistry, Geology, Geophysics, Biology, Computer Science and Informatics and Philosophy and History of Sciences. It performs research work and manages R&D projects.

Following specific agreements, every associate of FCiências.ID may act as a third party, supplying resources to FCiências.ID to execute its R&D projects. A third party agreement with FCUL is already in force. Every third party associate carries out, directly, its own share of work, not withstanding the full responsibility of FCiências.ID for the contracted scientific and technical work under specific R&D projects.

FCiências.ID is a taxable person of VAT and follows the Public Procurement Code. Public utility status was granted on 13-1-2022.

Part 4
Scientific projects

4.1 A novel model of elastoplasticity

The physical mechanism

Plasticity is a mechanism of deformation of solids that allows a body to deform beyond the elastic limit, without failure. Materials typically like metals have this property : first they deform in a reversible manner (the elastic regime), then in order to facilitate the deformation, some microstructure (the so-called dislocations) are activated, and by moving on some specific glide planes allow the body to deform beyond the yield stress.

Industrial applications

1. Manufacturing and Forming Processes
   — Metal Forming : Processes such as forging, rolling, extrusion, and deep drawing depend on the plastic behavior of metals to shape them effectively.
   — Polymer Molding : Thermoplastics can be molded into complex shapes due to their plasticity when heated.
2. 'New' material applications of dislocations and plasticity
   — Ni-Al, Ti-Al superalloys for jet engine and land-based power generation turbine discs and blades (high temperature)
   — High-strength, high ductility, light weight alloys for lower greenhouse gas emissions
   — Stress and defect management in semiconductor thin films (want thickest epitaxially laid film with no interface or threading dislocations)
   — Thermal mismatch stress management in chip interconnects.

Our model

Our model is novel in the sense that the equations we solve are not the classical ones : in particular the model is tensorial and high order. Our approach relies on the notion of incompatibility of the deformation that is related to the density of dislocations inside the body. We elaborate the model since 2014. It requires fine mathematical tools, sophisticated numerical methods, and a profound understanding of the physical mechanisms in play, notably Thermodynamics. We already have published 4 papers in distinguished journals since 2016. Two are currently in preparation.

Our team

The project is lead by Nicolas Van Goethem, member of CEMS.UL and professor at the Mathematics department of the Faculty of Science since 2008. NVG is an active researcher in the field of Applied mathematics and Mechanics for 25 years, with international background (UCLouvain, UCLondon, école Polytechnique de Palaiseau, UPisa, SISSA Trieste). The two researchers at the origin of the model, and devoted to its elaboration, are NVG and Samuel Amstutz, professor at the University of Avignon (former professor at école Polytechnique, France). The third senior member is Thien-Nga Lê, CNRS researcher at école Polytechnique (LMS laboratory - Material Science). Other members are in Barcelona (CIMNE), Notre-Dame University (USA).

Our needs

We wish to integrate **1 PhD student** and **1 post doc**, and also **2 master students** for smaller projects. The main part will be devoted to numerical simulations and physical understanding of features such as hardening, size effects, 3d and complex geometries.

4.2 Analysis of time series data via topological data analysis

The approach : Topological Data Analysis

Topological Data Analysis (TDA) is a novel field that emerged from applied topology and computational geometry around the beginning of the century. A difficult problem in data analysis is to determine the right scale at which to look at data. The recent success of TDA is due to its multi-scale approach to data analysis. This means that scale is seen as a parameter rather than a fixed constant, and data is analyzed at all scales at once. The advantage of a multi-scale approach is that a user can make an informed decision about the choice of the input parameter or scale used to look at data. TDA provides novel methods for three different problem areas :

1. Topological inference, i.e. infer information about the underlying shape of a data set.
2. Clustering, i.e., understand the connectivity of the data.
3. Topological signatures, i.e., provide signatures for data sets that are easier to compare and analyse than the data set itself.

The project

The main aim of the project is to develop mathematical and computational tools based on TDA to monitor and evaluate spatial time-series data ; to understand the key factors driving change in a complex system ; and to develop and explore different future scenarios for the underlying complex system. Our goal is to focus on three different types of time series data, i.e., land use data, engineering data and financial data. In this context, change can be related to irreversible damage to an eco-system, failure of an engine or severe loss of money on financial markets.

In short, we plan to utilize and extend key ideas of TDA to address the following questions :

— How to reveal early-warning signs of change in complex systems and how to accurately project it in general ?
— How to identify such warning signs in the underlying topological characteristics of the related time series data ?
— How to develop different future scenarios to project how complex systems evolve based on previous observations ?

We recently presented a proof-of-concept study with colleagues from the German technology-transfer company TWT Science & Innovation GmbH in which we used our approach in the context of predictive maintenance for airplane engines.

The team

The project is led by Florian Pausinger, member of CEMS.UL and professor at the Mathematics department of the Faculty of Sciences. FP is an active researcher in discrete and computational mathematics for 15 years and obtained his Phd under the supervision of Herbert Edelsbrunner who is one of the pioneers of TDA.

Our vision

Our vision is to position CEMS.UL as a national competence center for TDA in Portugal. We wish to create a forum in which different researchers from Portugal can exchange ideas and industry partners can ask for expertise. As a first step a new MSc course on TDA was created which was was offered for the first time in 2024/25. As a second step we plan to organize a workshop to build a national network and identify common interests within the Portuguese research community. As a third step we plan to build a strong research group in Lisbon.

Our needs

We wish to integrate **2 MSc students** - one from the Master program in Mathematics and one from the Master program in Financial Mathematics who will explore the potential of our ideas in different use cases. In addition, we wish to integrate **1 PhD student or post doc** to set up our computational pipeline, acquire data and develop tailored tools and approaches for the analysis of different types of time series data.

4.3 Mathematics for Forest Protection and Sustainability : Optimizing Access for Firefighters

The Problem

In Mediterranean countries, wildfires are among the most serious environmental threats. They destroy ecosystems, endanger rural communities, and cause major economic and social losses. One of the key factors determining how effectively a fire can be controlled is road access—the ability of firefighters to reach the affected areas safely and quickly.

In many forested landscapes, roads initially designed for management activities (such as silvicultural treatments, monitoring, or timber extraction) also serve as critical lifelines during wildfires, providing the only access routes to remote zones. However, most existing forest road networks were not planned with fire prevention or emergency response in mind. Some regions remain inaccessible, while others depend on narrow or dead-end roads that can become dangerous traps under extreme fire conditions.

Designing forest road systems that minimize environmental impact and construction costs while ensuring connectivity, safety, and resilience during wildfires is a complex problem that requires innovative modeling approaches.

The Modeling Approach

The project aims to develop advanced mathematical optimization models and algorithms for the design of forest road networks that can simultaneously :

— minimize road construction costs and environmental damages ;
— guarantee effective access to all relevant forest zones under normal conditions ;
— maintain functionality even when parts of the network become unusable during wildfires.

We will employ robust mixed-integer programming models that explicitly handle uncertainty in wildfire occurrence and spread, without requiring detailed probability distributions.

To explore the effects of different fire patterns, we will generate and analyze multiple simulated wildfire scenarios. These will allow the use of *distributionally robust optimization* methods, a recent approach in operations research that ensures solutions remain effective under a wide range of risk conditions.

The focus is on developing and integrating new optimization models, algorithmic methods, and machine learning techniques to provide a robust scientific foundation for future applications in forest planning and fire management.

The Team

The project brings together researchers from CEMS.UL with complementary expertise :

— Miguel Constantino and Agostinho Agra, from the Departamento de Ciências Matemáticas of the Faculdade de Ciências da Universidade de Lisboa (FCUL) ;
— Marta Mesquita, from the Instituto Superior de Agronomia da Universidade de Lisboa (ISA).

The team has extensive experience in mathematical modeling and optimization applied to forestry, with strong backgrounds in mixed-integer programming, network design, and robust optimization.

Our Needs

To carry out the project, we plan to involve :

— one **Master's student**, to develop and calibrate the wildfire simulation component ;

— one **postdoctoral researcher**, to formulate and test the optimization models and algorithms.

We seek financial support to fund these research positions, computational resources, and dissemination of the results obtained.

By supporting this initiative, partners will contribute to advancing research that combines mathematics, ecosystem sustainability, and wildfire resilience—helping to protect our forests, rural communities, and the environment for future generations.

4.4 Extracting Quantitative Knowledge from Proofs : Logical Tools for Reliable Computation and Optimization

The Problem

Modern computational methods in engineering, finance, and data science often rely on highly complex mathematical models and numerical solvers. However, even when convergence or correctness is proved mathematically, these proofs frequently remain qualitative – they guarantee existence or stability but give no effective bounds or rates of convergence. This lack of explicit quantitative information makes it difficult for engineers and scientists to evaluate how theoretical results translate into real-world performance.

The Logical Approach

This project aims to use tools from Proof Theory and functional interpretations to extract explicit quantitative content from mathematical proofs – a process known as proof mining. We will :

— Develop and apply new forms of functional interpretations (e.g., the Herbrandized or the recent Uniform functional interpretations) to Nonlinear Analysis, Optimization, and Partial Differential Equations.

— Produce computable bounds and rates of convergence from non-constructive mathematical proofs.

— Implement prototype tools that semi-automatically perform this proof-theoretical analysis on mathematical results.

The Center for Mathematical Studies (CEMS.UL) has a unique opportunity to build a leading research group in Applied Proof Theory / Proof Mining. The timing is ideal, as this field is entering a "second wave" of expansion : not only continuing its classical core applications (Fixed Point Theory, Convex Optimization, Ergodic Theory) but branching into new areas such as Stochastic Processes, Partial Differential Equations and other applied-mathematical domains.

Industrial Applications

— Optimization and Machine Learning : improving algorithms by extracting efficient rates of convergence.

— Computational Finance : obtaining explicit error bounds in stochastic and numerical methods.

— Engineering simulation : providing certified guarantees for iterative methods in control or mechanics.

Our Team

The project brings together researchers with complementary expertise :

— Fernando Ferreira (CEMS.UL) :a leading, internationally recognized expert in functional interpretations and the Foundations of Mathematics.
— Gilda Ferreira (CEMS.UL) : expert in Proof Theory and functional interpretations.
— Pedro Pinto (TU Darmstadt, joining CEMS.UL) : specialist in Proof Mining and its applications to Analysis. Having completed his postdoctoral work with Ulrich Kohlenbach (the founder of the proof mining research program) and recently secured a CEEC grant by Fundação para a Ciência e a Tecnologia, Pedro Pinto is excellently placed to spearhead this new research line in Lisbon.

Our Needs

We plan to integrate :

— **1 PhD student** to work on developing computational tools for proof interpretation.
— **1 postdoctoral researcher** to advance the theoretical framework and establish industrial case studies in Optimization, Finance, or Engineering.

This project will contribute to the development of reliable computational mathematics, bridging rigorous logical theory with industrially relevant quantitative information, and it will strengthen CEMS.UL's prospect to build a strong research group in Proof Mining.

Appendix

4.5 Annex 1

4.6 Annex 2