DyCon
DYNAMIC CONTROL

IMPACT DIMENSION OF THE DYCON RESEARCH PROJECT 2016 - 2022

ABSTRACT

This project aims at making a breakthrough contribution in the broad area of Control of Partial Differential Equations (PDE) and their numerical approximation methods by addressing key unsolved issues appearing systematically in real-life applications. To this end, we pursue three objectives:

1. *Contribute with new key theoretical methods and results*
2. *Develop the corresponding numerical tools*
3. *Build up new computational software, the DYCON-COMP computational platform, thereby bridging the gap to applications*

The field of PDEs, together with numerical approximation and simulation methods and control theory, have evolved significantly in the last decades in a cross-fertilization process, to address the challenging demands of industrial and cross-disciplinary applications. Despite these efforts, some of the key issues remain unsolved, either because of a lack of analytical understanding, of the absence of efficient numerical solvers, or of a combination of both. This project identifies and focuses on six key topics that play a central role in most of the processes arising in applications, but which are still poorly understood: control of parameter dependent problems; long time horizon control; control under constraints; inverse design of time-irreversible models; memory models and hybrid PDE/ODE models, and finite versus infinite-dimensional dynamical systems. These topics cannot be handled by superposing the state of the art in the various disciplines, due to the unexpected interactive phenomena that may emerge, for instance, in the fine numerical approximation of control problems. The coordinated and focused effort that we aim at developing is timely and much needed in order to solve these issues and bridge the gap from modelling to control, computer simulations and applications.

BRIEF EXPLANATION OF THE NEED THAT TRIGGERED THE PROJECT

DyCon's ambitious research programme has been developed at the intersection of three areas that have evolved rapidly in the last decades:

1 - Partial Differential Equations (PDE)
2 - Control Theory
3 - Numerical Analysis.

This impact report has been designed following the Horizon Europe requisites and tools (ex.canvas). This report considers the different dimensions of impact during the project lifecycle, the resources and efforts invested, and the outcomes and impact generated by the project.

ALIGNMENT WITH LOCAL, NATIONAL, EU AND INTERNATIONAL POLICIES AND PLANS

DyCon Project has based its research monitoring indicators on the following European references: European Research Area, Horizon Europe Framework Programme, Pillar 1-Excellence Science and ERC Working Programme 2015.

The scope of the DyCon research programme during its lifetime has demonstrated to be aligned with regional and national research programmes such as:

- The Spanish State Programme for R&D&I Oriented to the Challenges of Society (RETOS 2017) under the premise that each challenge constitutes an essential scientific-technical and social priority that must guide basic research activities of the agents of the Spanish System of Science, Technology and Innovation.

- The Basque Regional funding programme to support the performance of Collaborative Research, carried out by the Research, Development and Innovation Entities integrated in the Basque Network of Science, Technology and Innovation of the Basque Country, in the areas of specialization framed in the Plan for Science, Technology and Innovation Euskadi 2020.

SPECIFIC NEEDS

Scientific context

DyCon was envisaged to address research to understand and solve the control of partial differential equations (PDE) and its numerical analysis methods, through the development of new theoretical methods and numerical tools gathered on a computational platform (DyCon Toolbox).

Real-life applications

The theoretical and computational contributions of DyCon had an impact on different real-life applications such as healthcare, water management and energy.

Excellence researchers involvement

Over the 6-year period (2016 - 2022), DyCon has challenged the participation and contribution of international researchers through specific placement programmes. The PI, in cooperation with all team members, has managed to build multi and interdisciplinary and intersectoral connections. These working relations have facilitated the overall team involvement and success, even while confronting the contingencies posed by the COVID pandemic.

EXPECTED RESULTS

Objective 1

One of the expected outcomes of the DyCon project was to consolidate a rich international network of collaborators, leading to analytical and computational results, implying a significant leverage in the state of the art of the important field of PDE control and its numerical and computational counterparts. The project has successfully developed a robust research network of collaborators at two different levels:

1. The PI has not only consolidated a collaborative research network but has also facilitated research placements for researchers within several institutions with a total of 9 entities actively involved
2. The PI has actively delivered research dissemination activities in 22 universities and research centres

In addition, a total of 31 senior visitors have been involved in seminar events in the Host Institution and 18 young researchers from European and non-European institutions have been involved in the development of DyCon working packages.

The ERC-DyCon has also led to the implementation of two non-European ERC projects such as a NSFC-ERC project (2019-2021) and a NSF awardee with the NSF Framework United States and Europe Programme(2022)

Objective 2

Over the project period, the DyCon team has actively been involved in two regional and national projects on the energy sector in alignment with the European research priorities:

1. Analysis and identification of critical parameters for the stability of hybrid AC/DC grids (COSNET National and ROAD2DC regional projects)
2. New technologies to increase power density in electronic converters CONVADP (regional project)
3. Kinetic equations and Learning control- KiLearn (national project).

These other projects are aligned with the original goal of DyCon of addressing specific applications in sectors such as aviation aircrafts, water management or collective behavior.

TARGET GROUPS

- The international Mathematical research community, with special focus research teams in control theory.
- Engineering and Computer Science academic teams and research centers, as a way to enhance the multidisciplinary research and the array of potential users of mathematical control research results.
- Young researchers communities, in an effort to contribute to the training of the new generations of mathematicians.
- Public and private entities as potential users of the project results and outcomes.
- General public to enhance and convey the value of mathematics and its relevance in real-life. A particular effort was made on secondary school centers to stimulate young students mathematical vocation.

OUTCOMES

The ERC 2015 Work Programme aimed to a) lead to advances at the frontier of knowledge, b) set a clear and inspirational target for frontier research across Europe and c) maintain focus on excellence, encouraging initiative and combining simplicity and flexibility with accountability. The DyCon project has implemented novel methodologies to achieve high-quality scientific outcomes and train professionals in the field.
The main outcomes could be summarized as follows:

1. Consolidation of an international research network with 8 institutions through contract engagements, within the international community of mathematicians in the DyCon scientific areas.

2. Link between the international and regional innovation arenas through research projects developed in the Basque Region and Madrid. Cooperation in the "Women for Africa National Programme", addressing the STEM gap and the equal opportunities challenge.

3. Publication of 101 scientific research papers and direct participation on projects oriented to energy management (hybrid AC/DC grids and electronic converters).

4. Registering of the DyCon Computational platform in the Basque Government general register of intellectual property (17/03/2021).

5. Development and consolidation of knowledge on emerging topics in the interface between control theory and machine learning.

DISSEMINATION, COMMUNICATION AND EXPLOITATION MEASURES

Dissemination

(making sure that all results are freely available to the scientific community)

A total of 101 papers has been published during the 72 months project period.
The dissemination indicators can be summarized as follows: 62% cited in WoS and 74% in Scopus, 86% are covered by JCR quartiles (JCR Q1=57%, JCR Q2=26%, JCR Q3=10.3%, and 5.7% JCR Q4

Real-life applications

(increasing the public visibility of the project and its results using accessible language)

The PI has actively been involved in different activities enhancing the public awareness on the relevance of mathematics, and its applications. These efforts are gathered in the dissemination webpage: https://cmc.deusto.eus/enzuazua/

Exploitation

(making concrete use of results)

DyCon has developed specific outcomes on its 7 working packages. The development of the project has also led to new perspectives in the interface between Control Theory and Machine Learning. This has led to technological transfer agreements with the Basque Artificial Intelligence company Sherpa.ai for the period 2021-2023

DyCon has designed and developed a number of internal procedures and strategies to facilitate the visibility of the project's outcomes:

The DyCon Computational Toolbox: A platform focusing on the Matlab library for nonlinear optimal control problems

The DyCon Blog: A web space to easily disseminate the research results (86 research entry blogs published).

DyCon Toolbox

DyConBlog

IMPACTS

Scientific impact

DyCon researchers have engaged careers in institutions such as Massachusetts Institute of Technology, Imperial College in London and Cambridge University, amongst others.

In addition, the project PI has been awarded an Alexander von Humboldt Professorship (2019) and the 2022 W.T. and Idalia Reid Prize of the SIAM, Society for Industrial and Applied Mathematics.

Knowledge transfer

Cooperation with Sherpa.ai.

DyCon has contributed to the successful interdisciplinary collaboration between universities and research centers through regional Basque projects on energy applications.

Societal

DyCon has pursued an active policy for gender equal opportunities through its public international calls for PhD students and postdocs.

The PI has received two societal awards such as the "Txopitea eta Pakea Award" of the Eibar Municipality (2020) and DEIA Top Talent Sariak (2021), Bilbao.