SUCCESS STORIES BOOK

2026 EDITION

Edited by M. Cruz and P. Quintela

EU MATHS IN

PREFACE

In recent years, the competitiveness and resilience of the productive sector has become vitally important for a strong European industry. At the same time, the complexity of the challenges that companies and organisations must face to ensure their sustainability has increased exponentially. On the other hand, the proliferation of tools in artificial intelligence, machine learning, or smart algorithms, in many cases with a debatable guarantee of use, have opened up a forest of options for industry that makes it difficult for them to identify the best way to implement the best solution in the company.

In this context, the mathematical tools of Modelling, Simulation and Optimisation in a Rich Digital Environment (MSO-DE) help to address the challenges following a scientific, rigorous, efficient, and secure model that also allows the company to incorporate solutions in the state of the art of the challenge posed.

To show the great potential that MSO-DE technologies have already shown in industry, EU-MATHS-IN is pleased to invite you to browse through these pages with almost fifty success stories of Academy-Industry collaboration.

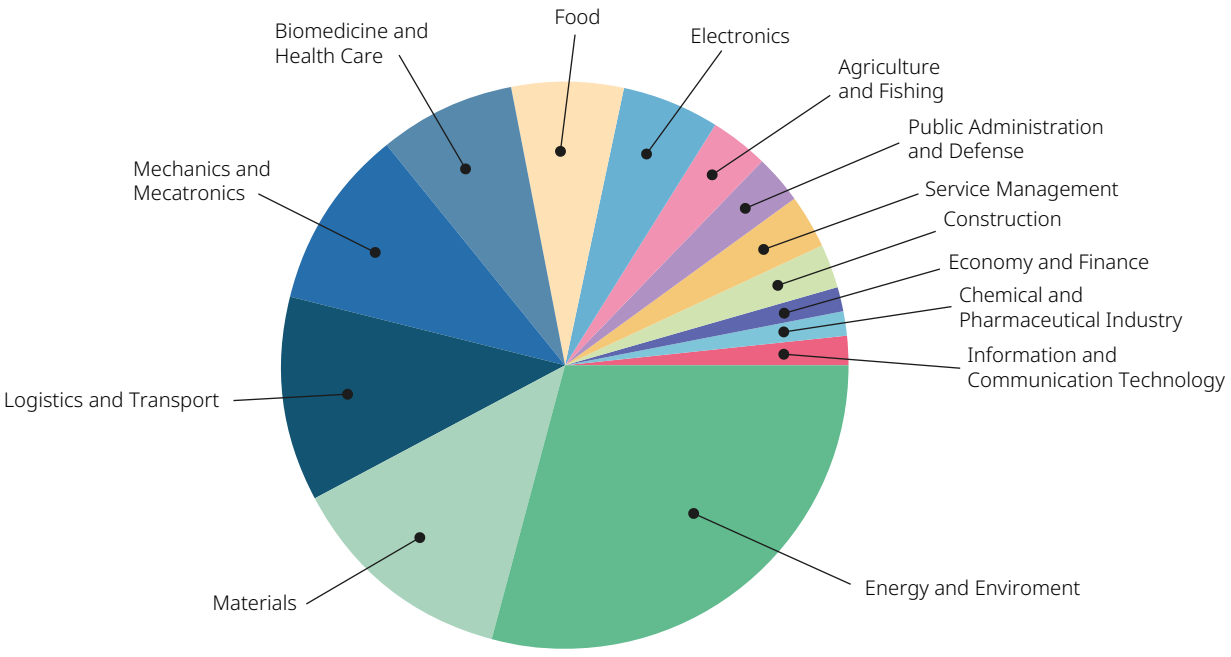
We invite you to consult their details convinced that they will be a source of inspiration for your organisation.

About thirty European research centres of excellence in the field of Industrial Mathematics and more than fifty companies are involved in the success stories presented in this e-book.

As presented in the next figure, the Success Stories underlying challenges arose from a wide range of productive sectors, demonstrating how MSO-DE technologies are transversal to almost all industrial and institutional sectors.

For ease of use, this e-book has two indexes: an index by productivity sector; and another one by EU-MATHS-IN national networks.

EU-MATHS-IN would like to invite you to consult the pre-diagnostic and diagnostic services offered by its OpenDesk (https://opendesk.eu-maths-in.eu/), a European one-stop-shop that facilitates the connection of each business challenge with the most experienced European experts who can help solve them.



Finally, we would like to thank all the companies and organisations that have actively participated in these success stories and have authorised their publication:

	COMPANIES OR ORGANIZATIONS
A-B	ADHEX Technologies (ES) ; AFG (FR) ; Bruker Daltonik GmbH (DE).
C	CESGA - Centro de Supercomputación de Galicia (ES); CIC energiGUNE (ES); CIE Galfor (ES); COFRICO (ES); Coremain S.L.U. (ES) ; CorWave SA (FR).
D-E	Danieli Group (IT); EcoMT Ecomanagement Technology (ES); Ekinnox (FR); ENGIE Green (FR); ERSI Group (ES).
F	FERROGLOBE Advancing Materials Innovation (ES); Fincantieri S.p.A. (IT); Fundiciones Rey (ES).
G-H	GOMPUTE (ES); Hager Electro SAS (FR).
I	i4sea (BR); iAuditoria y Gestión Calidad (ES); Iberdrola España (ES); IECA (ES); IEFluids (IT); INOVAlabs (ES).
J-L	Johnson & Johnson (CH); Lantek (ES); LifyAir (FR).
M	McLLOYD (FR); MCY - Montecarloyachts (IT); MICAD - Marine Innovation Consulting and Design (IT); MicrodB (FR) ; Microflown Technologies (NL) ; MICROGATE (IT).
N-P	NEIKER (ES); Nors group (PT); NV Bekaert SA (BE); Pollen Metrology (FR); Proteopath GmbH (DE).
R	Reganosa (ES); REPSOL (ES); RS2N SAS (FR).
S	Safety Line (FR); SARI S.A. - NORS Group (PT); Scorelab (FR); Seguros Lagun Aro (ES); Smartgeo Solutions, Lda. (PT).
T-W	TexiSense (FR); TwinSight (FR); UmanIT (ES); VARDA Space Industries (US); VICUSdt (ES); WUJI & CO (FR).

VIEW BY PRODUCTIVITY SECTOR

VIEW BY NATIONAL NETWORK

This e-book intends to be updated frequently.
This is the June 2026 version.
Please check the EU-MATHS-IN website to obtain the most recent version.

EU-MATHS-IN Success story

COMPANY
IECA
(Spanish Institute of the Cement and Applications)

RESEARCH CENTRE
IMAG, Universidad de Granada

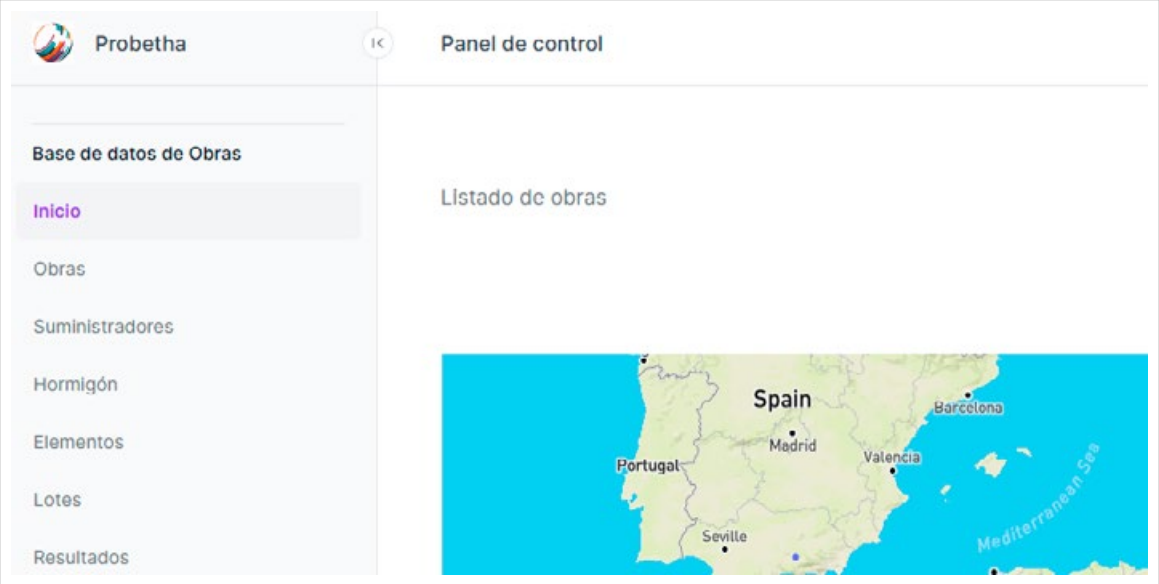
PRODUCTIVE SECTOR
Construction

More info

SS_050_2025

PROBETHA

A complete and practical software for the concrete quality control.



Control panel of the concrete quality control application.

PROBLEM DESCRIPTION

Consulting and adequate application of the complicated new quality control techniques for the concrete used in Spanish projects (Building and Civil Engineering).

CHALLENGES AND GOALS

The main challenges of the project were the correct interpretation and mathematical formulation of the criteria of the new established standards, and the final goal was the final implementation of all these complicated rules in a complete software that can accomplish all the process.

MATHEMATICAL AND COMPUTATIONAL METHODS

The main mathematical techniques employed consist of the adequate statistical techniques for the quality control of the concrete, but also some necessary extrapolation techniques when the first results of the test tubes from the bulk batches are initially non-compliant, requiring subsequent re-measurements and re-adjustment of all calculations.

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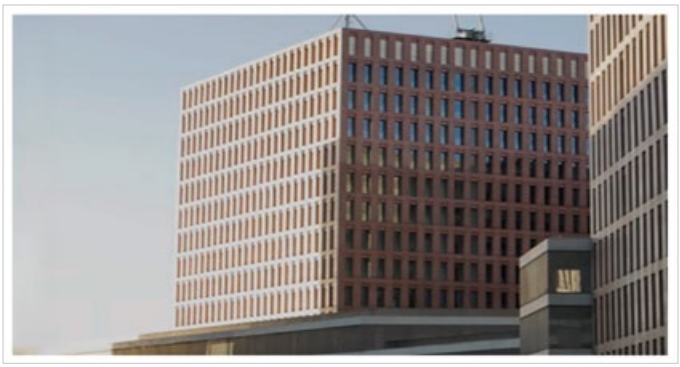

Concrete quality control in edification.

Concrete quality control in civil engineering

RESULTS AND BENEFITS

The IECA Association is a Spanish institution for scientific and technical research in the field of cement and its applications. One of its main goals is the advice and technical assistance to cement users as well as promoting the development and application of correct quality standards in the manufacture and application of cement and concrete in all projects and constructions carried out in Spain.

So, for these mandatory quality controls, a comprehensive software program that correctly performs all the calculations is invaluable.

The main benefits for the Spanish Cement Institute and many important construction companies would be a significant saving of time in the concrete quality control, both in buildings and civil engineering projects.

IMAG: Mathematics Institute of the UGR.

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Success story

COMPANY
ERSI Group

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IMAG, Universidad de Granada

PRODUCTIVE SECTOR
Construction

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PILES REINFORCEMENT

Asymmetric piles in large concrete structures.
Study and practical implementation.

Reinforcing steel required for the construction of the corresponding asymmetric pile.

PROBLEM DESCRIPTION

Consulting and research on the design and implementation of asymmetric reinforcement of piles in large concrete structures.

CHALLENGES AND GOALS

The main challenges are the design of asymmetric reinforcement of piles with suitable N-M interaction diagrams in the equilibrium equations at failure for the structure to be designed and built, but using asymmetric piles instead of the usual ones, with the corresponding saving of material (mainly steel).

MATHEMATICAL AND COMPUTATIONAL METHODS

The main mathematical techniques employed consist of the application and adjustment of the appropriate physical equilibrium equations, which are greatly complicated by the lack of symmetry, accompanied by appropriate optimization techniques, in order to minimize the use of steel in the piles for the design and construction of big civil projects.

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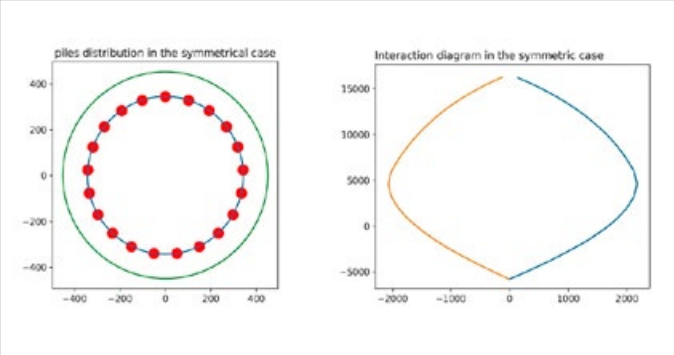
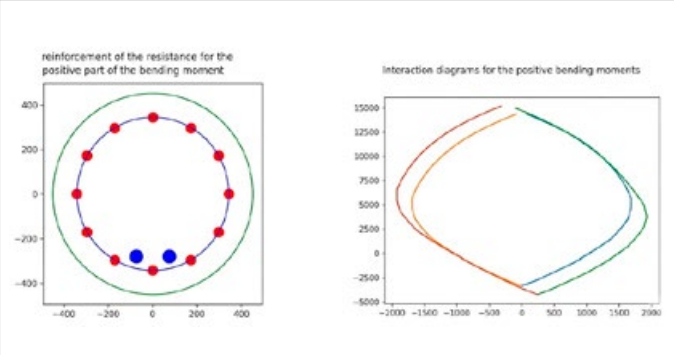


N-M interaction diagram in the symmetric case.



N-M interaction diagram in the asymmetric case.

RESULTS AND BENEFITS

The main results of the collaboration with the company was the theoretical study and posterior implementation in an executable computer program of all the complicated physical and mathematical considerations and computations.

In order to can replace the usual symmetric piles considered in big civil engineering projects by the equivalent asymmetric ones, with similar behavior in terms of resistance and N-M equilibrium diagrams, but with a significant saving in the use of steel in its construction.

The main benefits for the company and their customers would be a significant saving of material (especially steel) in the design and manufacture of the asymmetric piles that would eventually replace the usual symmetric ones in big civil engineering projects.

IMAG: Mathematics Institute of the UGR.

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Success story

COMPANY
VARDA Space Industries

RESEARCH CENTRE
University of Limerick, Taighde Éireann Research Ireland, MACSI, SSPC.

PRODUCTIVE SECTOR
Chemical and Pharmaceutical Industry

Digital Twin

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SS_048_2025

MEDICINES FROM SPACE

Understanding and controlling polymorphism in crystallization for pharmaceutical production in space.

The launch of W-2 capsule as part of the Transporter-12 rideshare mission with SpaceX on Jan. 14, 2025.

PROBLEM DESCRIPTION

How does microgravity influence crystal growth and polymorphism, and why do otherwise identical pharmaceutical crystal manufacturing processes produce different crystal structures (polymorphs) on Earth and in space?

CHALLENGES AND GOALS

- ✔ Understand the interplay of gravity, sedimentation and crystallization;
- ✔ Predict crystal growth and polymorphism of a test molecule;
- ✔ Support development of in-space pharmaceutical manufacturing platforms.

MATHEMATICAL AND COMPUTATIONAL METHODS

Crystallization was modelled by coupling nonlinear hyperbolic partial differential equations computing the evolving number of crystal polymorphs of each size with an ordinary differential equation for solute concentration. The method of characteristics is used to analyze moving shocks while a high-resolution Godunov-type method is used to obtain accurate numerical solutions.

The interplay between sedimentation and crystallization was modelled with coupled nonlinear ordinary and integro-differential equations. Asymptotic analysis is used to identify distinct physical regimes and provide simplified analytical solutions.

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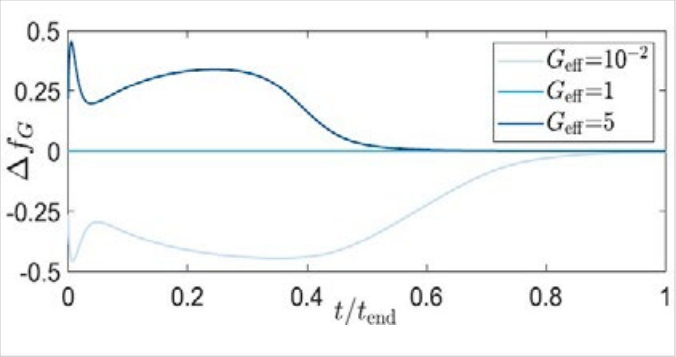
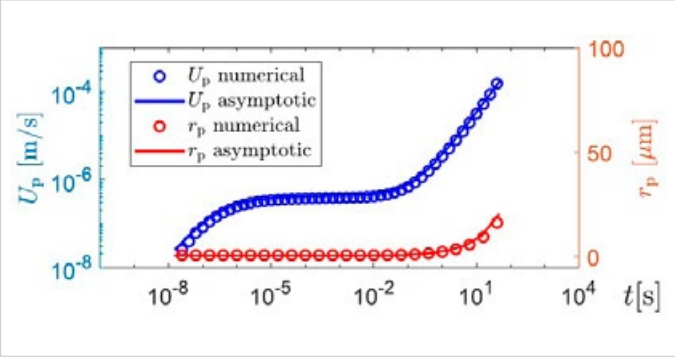


Relative change in mass yield of a polymorph for crystallization at varying gravities.



Comparison of numerical and asymptotic particle radius (r_p) and velocity (U_p) during sedimentation.

RESULTS AND BENEFITS

The framework provided insights on polymorph nucleation and the impact of gravity on growth and sedimentation processes relevant to pharmaceutical crystallization. The adopted methodology reduced simulation costs while preserving accuracy.

The models also revealed critical distinctions between concurrent and sequential sedimentation–growth regimes and explained how gravity intensity may alter crystallization pathways.

Numerical simulations are advancing our understanding of gravity's role in drug manufacturing and providing a framework that may shorten R&D cycles and reduce experimental costs.

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PRODUCTIVE SECTOR
Logistics and Transport

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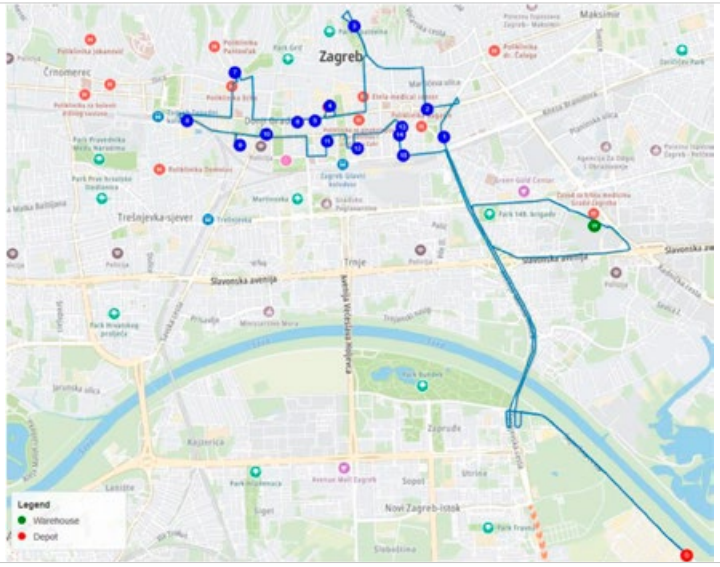
SS_047_2025

SMART WASTE

Smart waste collection with integrated sensors. Forecasting fill levels and optimizing collection routes using real-time data.



Optimized waste collection route.

PROBLEM DESCRIPTION

Sotkon, part of the Nors' Ventures segment and specialized in technological solutions for waste management, installs sensors in recycling containers to monitor fill levels in real time. Using this data, the challenge was to plan truck routes that improve waste collection efficiency, by ensuring waste is collected exactly when and where it is needed.

CHALLENGES AND GOALS

- ✔ Forecast container fill levels and anticipate daily collection needs.
- ✔ Manage daily fluctuations in container fill levels.
- ✔ Plan efficient routes, respecting logistical constraints.
- ✔ Minimize costs and environmental impact.

MATHEMATICAL AND COMPUTATIONAL METHODS

The project started by developing a mathematical model to predict the filling levels of recycling containers in the forthcoming hours. The model was used to plan waste collection more effectively through the TOPSIS method, which prioritizes collection based on factors like urgency and location.

The second stage of the project relied on an algorithm that runs three different routing methods — Clarke and Wright, Genetic Algorithm and Ant Colony — to return the best solution. Since the collection points change each day, this approach uses the strengths of each method to find the most efficient solution every time.

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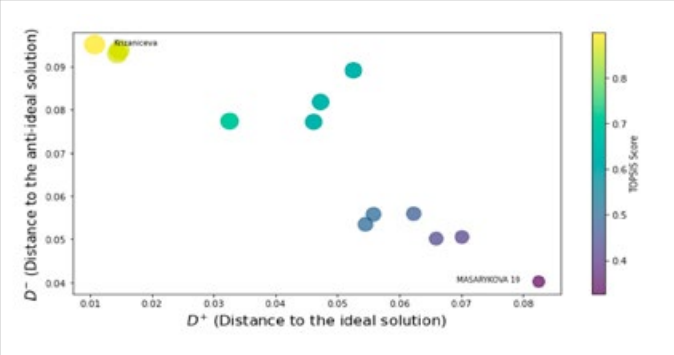
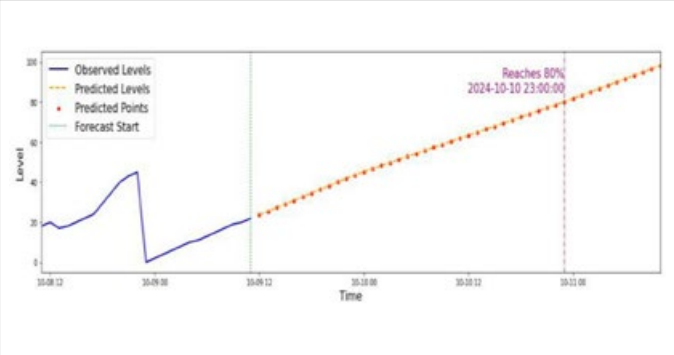


TOPSIS: D^+ vs. D^- positioning of containers.



Forecast of container fill level.

RESULTS AND BENEFITS

The collaboration yielded two key benefits: the anticipation of collection needs and the optimization of resources. By prioritizing the most suitable containers, efficiency increased, and the routing algorithm reduced the distance travelled by about 11.5% per route.

Additionally, the percentage of containers collected that were filled above 80% — the company's ideal threshold — increased from 21.8% to 51.3%, ensuring that the collection is made primarily where it is most needed.

Overall, the project reduced costs, minimized environmental impact, and improved service quality.

This project enabled the company to know when and in which order to collect waste, reducing in 11.5% the distance travelled by the trucks and duplicating the accuracy on which bins are to be collected.

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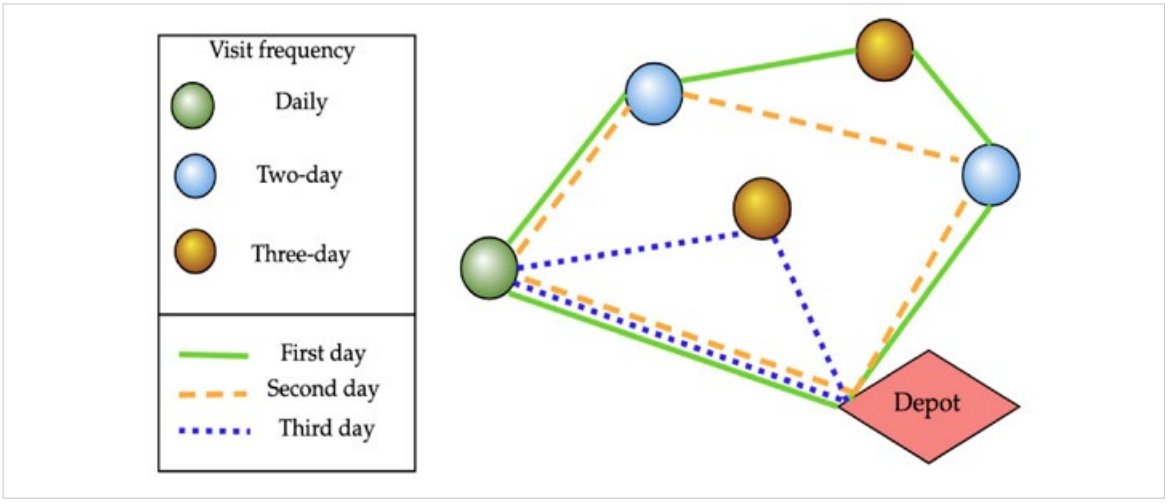
SMART ROUTING

Smart routing with genetic algorithms.
Optimising sales teams scheduling.



Simplified representation of the vehicle routing problem to be solved.

PROBLEM DESCRIPTION

Nors Construction Equipment Canada ST, one of the Nors companies with clients spread all around the Canadian territory, needed to develop a model in order to coordinate and plan the commercial teams' agenda in an efficient manner.

This would imply to optimize the schedules and the commercial teams' agenda for several weeks subject to client-specific frequencies, time constraints, and geographic dispersion.

CHALLENGES AND GOALS

- ✔ Efficient optimization of sales routes over extended periods.
- ✔ Handling complex client visit and time constraints.
- ✔ Balancing daily workload while minimizing total travel time.

MATHEMATICAL AND COMPUTATIONAL METHODS

In this project, we developed and implemented a smart route optimisation system based on genetic algorithms to plan sales team visits over several months.

The method works by simulating evolution constrained by natural selection: it generates many possible schedules and keeps improving them through selection, crossover, and mutation. Each schedule is scored based on travel time, workload balance, and how well it meets client visit rules.

To improve the route further, we apply two other optimisation methods: 2-opt, which reshuffles visits to shorten travel, and simulated annealing that mimics the process of annealing in metallurgy. The solution runs efficiently on standard computers, making it practical for real-world sales planning.

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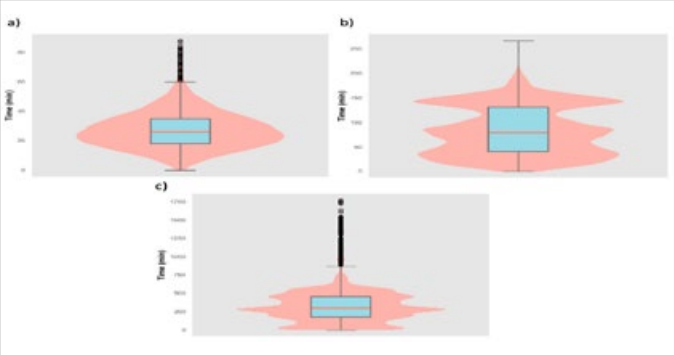
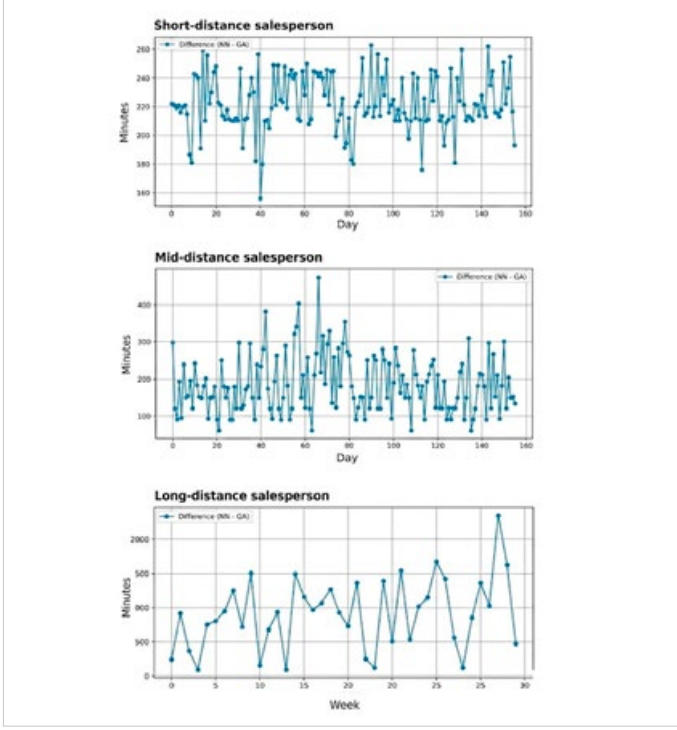


Boxplots and violin plots comparing the travel time distributions of each salesperson.



Differences in daily travel time between the NN and GA models for each in-person day.

RESULTS AND BENEFITS

We developed a smart route optimization software using genetic algorithms that efficiently plans multi-week sales visits while respecting real-world constraints like client frequencies and time windows.

Even without benchmark datasets, the model showed strong results, cutting travel time per client by up to 69% compared to the commonly used Nearest Neighbour method, which mimics the intuition of the salesperson.

This highlights its ability to generate highly efficient, constraint-compliant routes, delivering clear logistical and operational benefits for sales teams working across diverse regions.

The solution delivers smart, efficient, and cost reducing sales routes planning by cutting the commercial teams' travel time up to 69%, respecting visit constraints, and boosting overall team productivity.

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PRODUCTIVE SECTOR
Service Management

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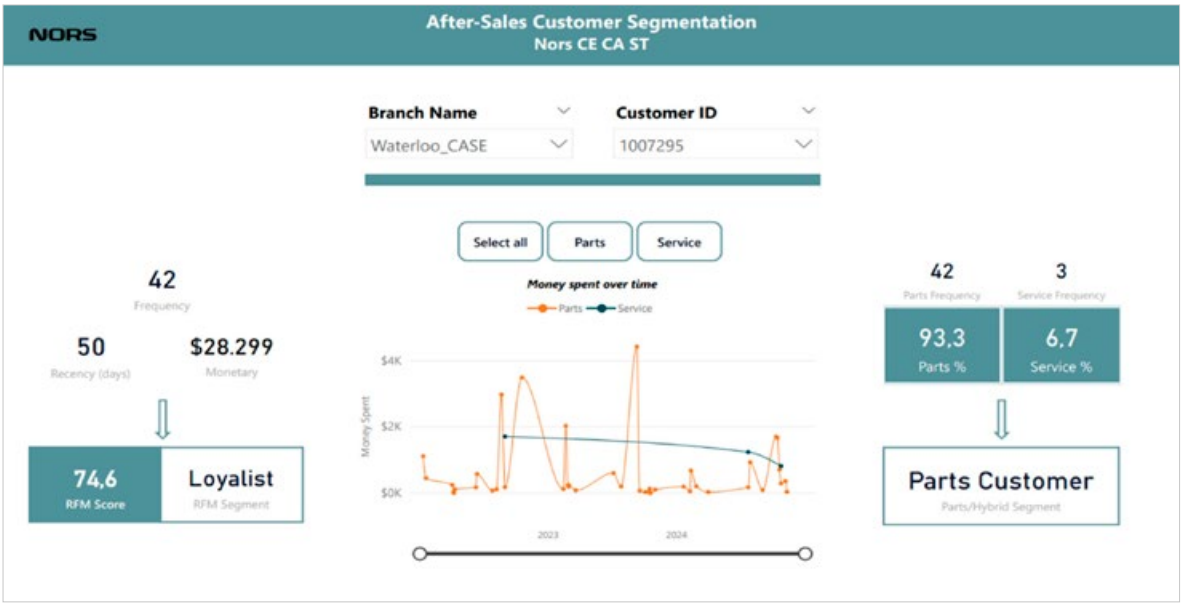
AFTER-SALES

Classification of customers into well-defined after-sales segments, providing the company with a deeper understanding of client behavior across branches.



Graphic User Interface developed.

PROBLEM DESCRIPTION

Nors Trucks and Buses Portugal RT, one of the Nors Group companies would like to strategically segment after-sales customers across multiple branches to boost service efficiency and parts sales in the heavy machinery industry.

CHALLENGES AND GOALS

The main goal was to implement a customer segmentation approach applicable across all company branches, despite their differing customer volumes and profiles.

A key challenge was adapting the segmentation to the specificities of the business context, where customer behavior varies significantly between regions.

MATHEMATICAL AND COMPUTATIONAL METHODS

The main segmentation technique applied was the RFM (Recency, Frequency, Monetary) model, using a scoring system to classify customers based on their after-sales purchasing behavior.

The model was implemented using Python, with data pre-processing, scoring computation, and customer grouping performed programmatically.

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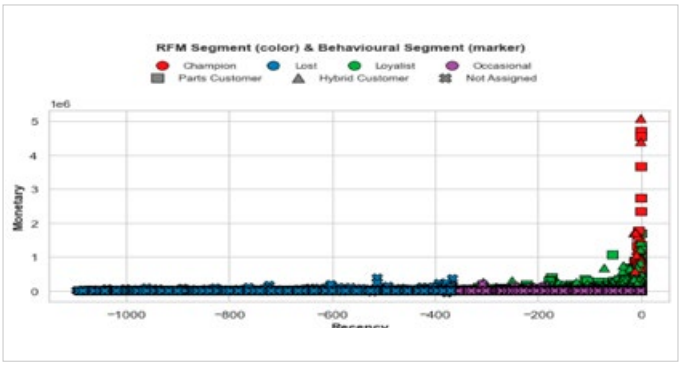
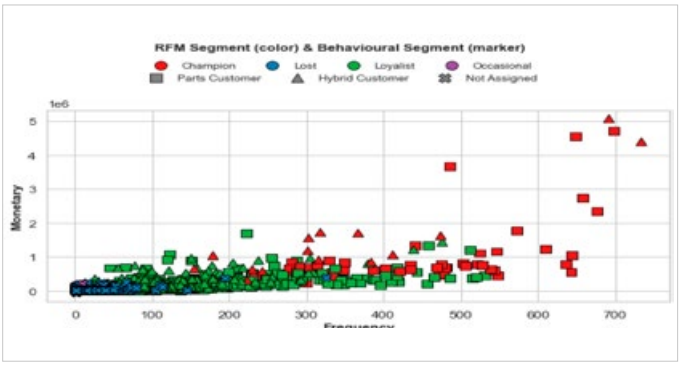


Segmentation Results –Recency vs Monetary.



Segmentation Results –Frequency vs Monetary

RESULTS AND BENEFITS

The project resulted in the classification of customers into well-defined after-sales segments, providing the company with a deeper understanding of client behavior across branches.

This segmentation serves as a valuable decision-support tool, enabling more targeted marketing campaigns, improved service quality, and a stronger customer relationship management strategy. Ultimately, it contributes to enhanced operational efficiency and increased profitability, by aligning commercial actions with customer needs and potential.

Improved customer knowledge and segmentation aim to enable more strategic decisions, better service quality, and increased profit ability across all branches.

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COMPANY
Johnson&Johnson

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MIT - Center for Transportation & Logistics

PRODUCTIVE SECTOR
Logistics and Transport

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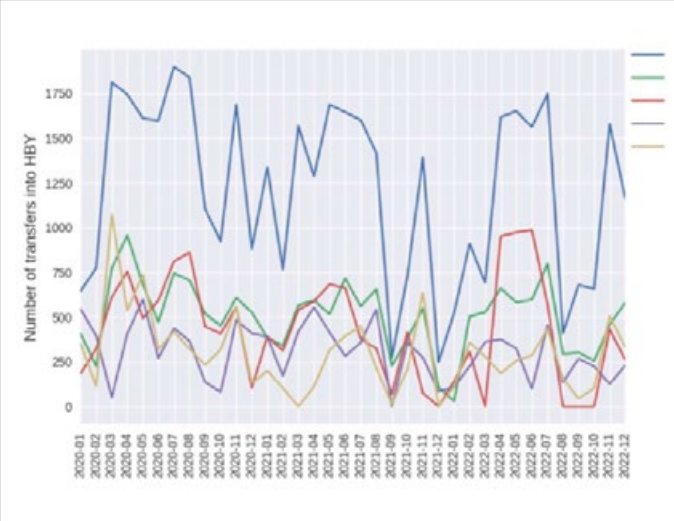
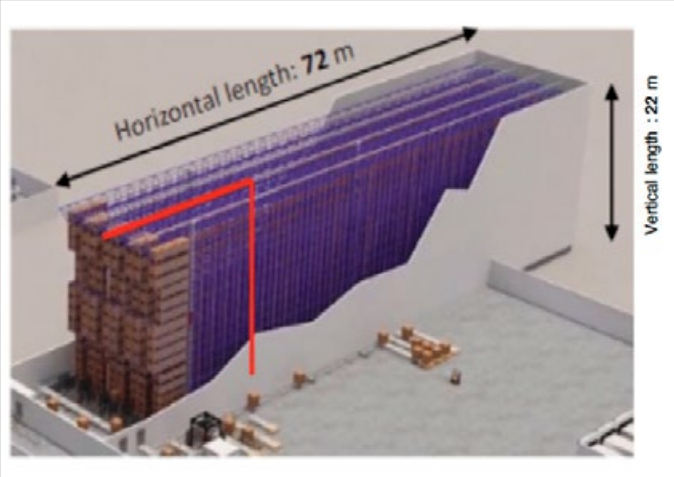
AI FOR WAREHOUSES

A new generation of AI-empowered warehouses.
A two-stage approach to minimize material movements in a fully automated warehouse.



Example of monthly transfers for top 5 materials.



Schematic of dimensions of the automated warehouse.

PROBLEM DESCRIPTION

In the context of a fully automated warehouse, can AI help us reduce material movements, decrease energy consumption and lower wear and tear on the equipment?

CHALLENGES AND GOALS

The goal of this collaboration is to develop an approach to locate the storage of materials within the warehouse by minimizing the distance the crane travels. The full optimization problem of material location assignment itself is complicated. We first need to predict the material movements and make assumptions to keep the optimization problem more manageable.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Deep Neural Networks are a type of artificial neural network that consists of multiple layers of interconnected neurons or units where the weights associated with each connection are adjusted to minimize the error between its predictions and the actual target values. Two famous architectures are Feedforward Neural Networks (FNN) and Long-Short Term Memory Networks (LSTMs).

- ✔ Mathematical Optimization is a field of mathematics and computer science that deals with finding the best solution from a set of possible solutions to a particular problem. It requires an objective function, constraints and an optimization strategy.

  $\min f(x)$
  $\text{st. } g_j(x) \leq 0,\ j = 1, \ldots, p,$
  $h_i(x) = 0,\ i = 1, \ldots, m,$

  where $g_j h_i : R^n \rightarrow R$ are inequality and equality constraint functions, respectively.

- ✔ Bayesian Optimization is a systematic approach to hyperparameter tuning that uses probabilistic modeling and acquisition functions to efficiently search for the best hyperparameter configuration while minimizing the number of objective function evaluations.

EU-MATHS-IN
Success story

COMPANY
Johnson&Johnson

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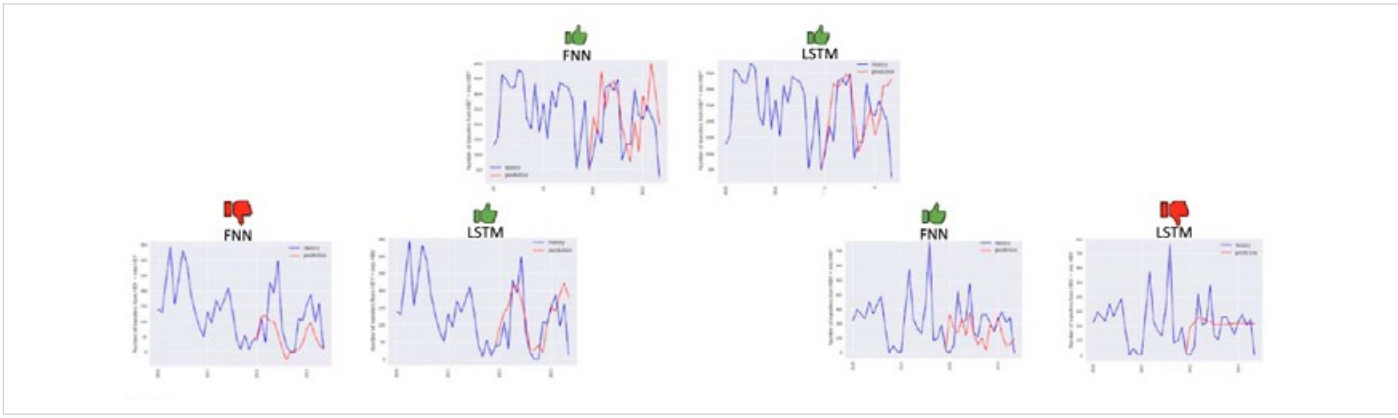
AI FOR WAREHOUSES

A new generation of AI-empowered warehouses. A two-stage approach to minimize material movements in a fully automated warehouse.



The DNN models can overall capture the qualitative behavior of the curves

RESULTS AND BENEFITS

The underlying mathematical novelty was to design a two-stage approach that redefines the material categories and their placement within the warehouse. To achieve that, we first leveraged the history of transfers to forecast the amount of monthly movements for each material using two models borrowed from the Deep Neural Networks space: FNNs and LSTMs.

Then we optimized the storage of materials within the warehouse by minimizing the distance the crane travels subject to space, allocation and assignment constraints.

A novel method to help streamline warehouse operations, improving efficiency and cost-effectiveness which represents a significant advancement in the field of logistics and supply chain management.

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COMPANY
Iberdrola

RESEARCH CENTRE
Basque Center for Applied Mathematics

PRODUCTIVE SECTOR
Energy and environment

Digital Twin

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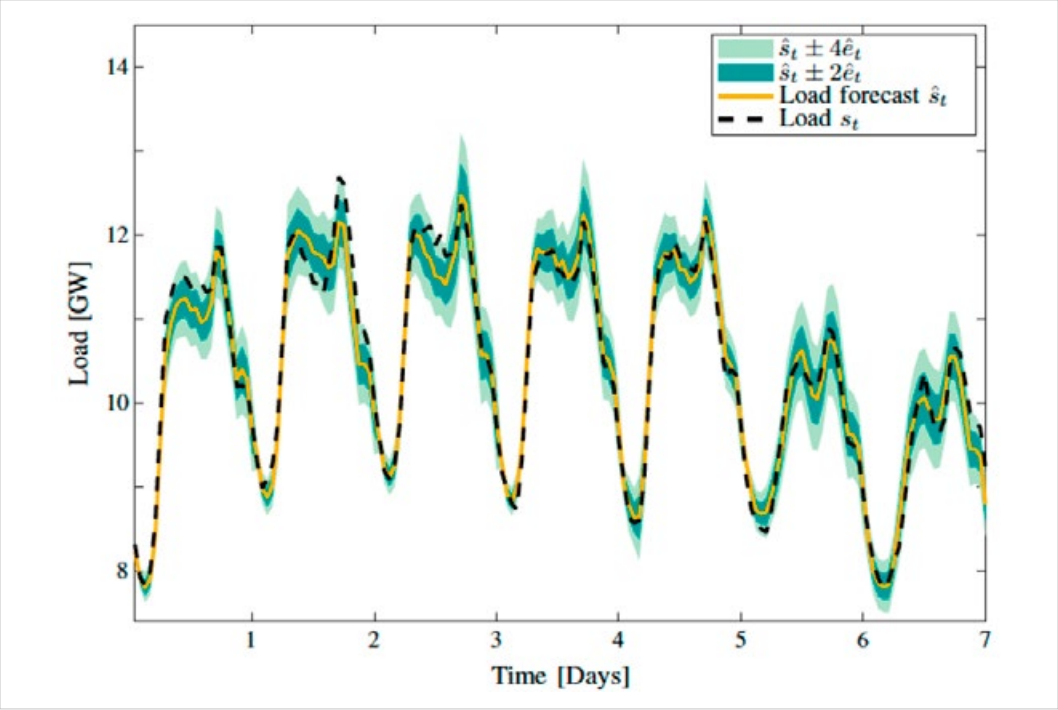
AI4EP

Machine learning for energy forecasting. Supervised learning solutions for energy-related forecasting problems.



The proposed methods obtain forecasts together with reliable uncertainty assessments.

PROBLEM DESCRIPTION

Load and energy price forecasting is crucial for multiple energy management tasks such as scheduling generation capacity, planning supply and demand, and minimizing energy trade costs.

CHALLENGES AND GOALS

Coping with the challenges arising from the dynamic changes in consumption patterns (concept drift) and intrinsic uncertainty in load demand and financial energy related variables.

MATHEMATICAL AND COMPUTATIONAL METHODS

We propose methods for load and price forecasting that can assess uncertainties in load demand and price and adapt to changes in consumption and cost patterns.

We develop algorithms that obtain predictions using hundreds of models updated with the most recent real data.

We develop energy price forecasting techniques that obtain predictions using a l ong short term memory (neuronal network) daily retrained with the most recent data.

COMPANY
Iberdrola

RESEARCH CENTRE
Basque Center for Applied Mathematics

PRODUCTIVE SECTOR
Energy and environment

Digital Twin

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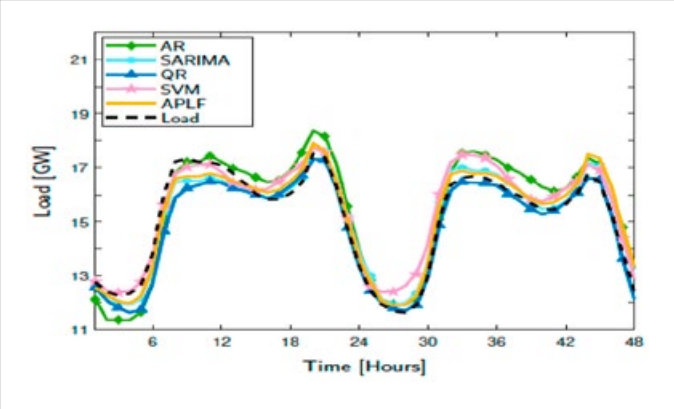
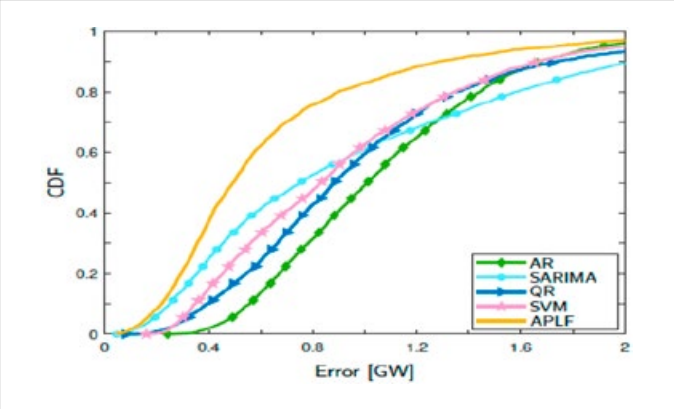
SS_043_2023

AI4EP

Machine learning for energy forecasting. Supervised learning solutions for energy-related forecasting problems.



Load demand in New England.



CDFs of prediction error.

RESULTS AND BENEFITS

The proposed APLF methods can assess energy-related variable uncertainties and adapt to changes in variable patterns. The numerical results show that the proposed methods can significantly improve forecasting performance in a wide range of scenarios using efficient and flexible algorithms for adaptive online learning. This achievement is further fortified by a collaborative partnership with IBERDROLA under the IA4TES project. The combined efforts with IBERDROLA's finance department have significantly help to delineate the main research objectives and methodological approaches.

Works published in high impact journals ''Probabilistic Load Forecasting Based on Adaptive Online Learning" in IEEE Transactions on Power Systems, 2021.

Best applied contribution in the Statistical Field awarded by SEIO-BBVA Foundation, 2022.

Appearance in national media (e.g., Antena 3) and RMSE newsletter.

Basque Center for Applied Mathematics.

EU-MATHS-IN Success story

COMPANY
Danieli Group

RESEARCH CENTRE
CITMAga, USC, SISSA

PRODUCTIVE SECTOR
Materials

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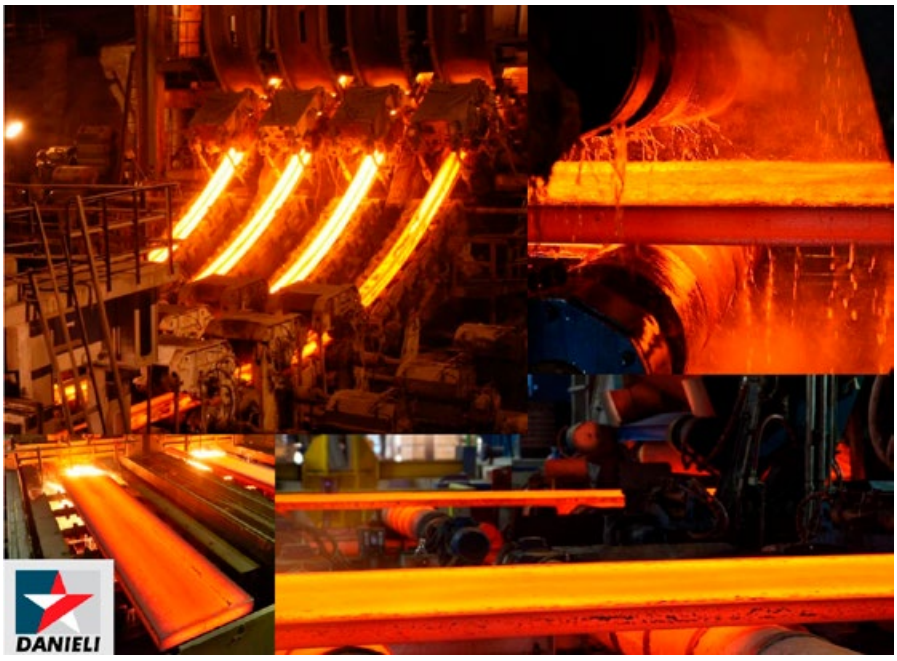
SS_042_2023

DANIELI GROUP

Monitoring Tool for Steel Continuous Casting Mold.



Overview of the different machineries involved in the continous casting process.

PROBLEM DESCRIPTION

To properly monitor a continuous casting mold, to know the mold-steel heat flux is crucial. This quantity is not measurable directly, so the objective of this project was to estimate it given some pointwise temperature measurements provided by thermocouples located in the interior of the mold plates.

CHALLENGES AND GOALS

This data assimilation problem comes under the category of inverse problems. As such, it is an ill-posed problem that requires regularization techniques for its solution. In general, these techniques are very computationally expensive but, being this a monitoring problem, we require the estimation of the mold-steel heat flux in real-time.

Then, the goal of this project is to develop novel methodologies meet the real-time requirement of the project.

MATHEMATICAL AND COMPUTATIONAL METHODS

We can divide this problem in three phases: modelling the heat transfer in the mold, solve the data assimilation problem, and achieve real-time performances. In modelling the mold, we had the mold plates as computational domain and a heat conduction model. For the estimation of the heat flux, we used a deterministic, optimal control framework. In this framework, we exploited a parameterization of the sought heat flux with the objective of reducing the computational costs and regularize the problem. Finally, to achieve real-time performances, we developed novel model order reduction techniques.

COMPANY
Danieli Group

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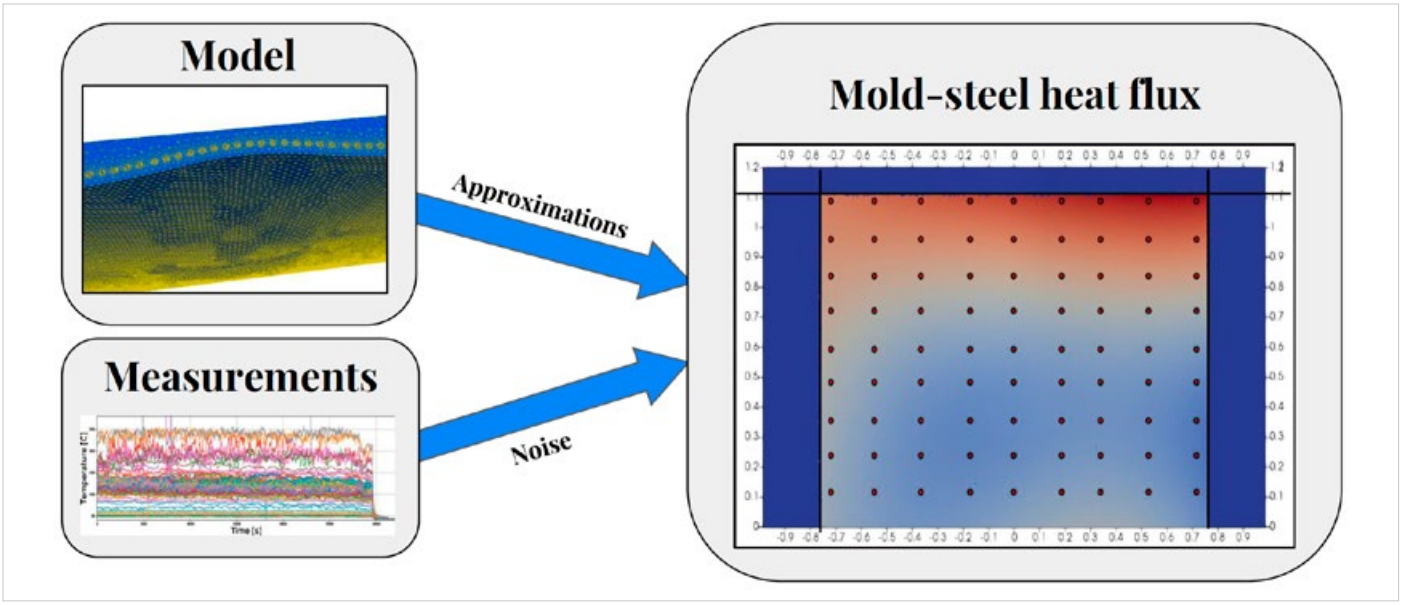
SS_042_2023

DANIELI GROUP

Monitoring Tool for Steel Continuous Casting Mold.



Schematic of the data assimilation process.

RESULTS AND BENEFITS

We equipped the company with a mathematical tool that provides excellent estimations of the mold-steel heat flux in réal-time. This real-time estimation allows a fast detection of dangerous casting issues and the monitoring of the genera mold behaviour. Finally, unlike all previous methods, the developed one does not rely on the caster operator experience and can be applied on any mold geometry.

The developed methodologies provide a reliable tool for the monitoring of the mold behaviour. It makes a fast and accurate detection of any casting issue increasing safety, productivity, and quality of steel continuous casters.

EU-MATHS-IN
Success story

COMPANY
Lify Air

RESEARCH CENTRE
Institut de recherche mathématique de Rennes

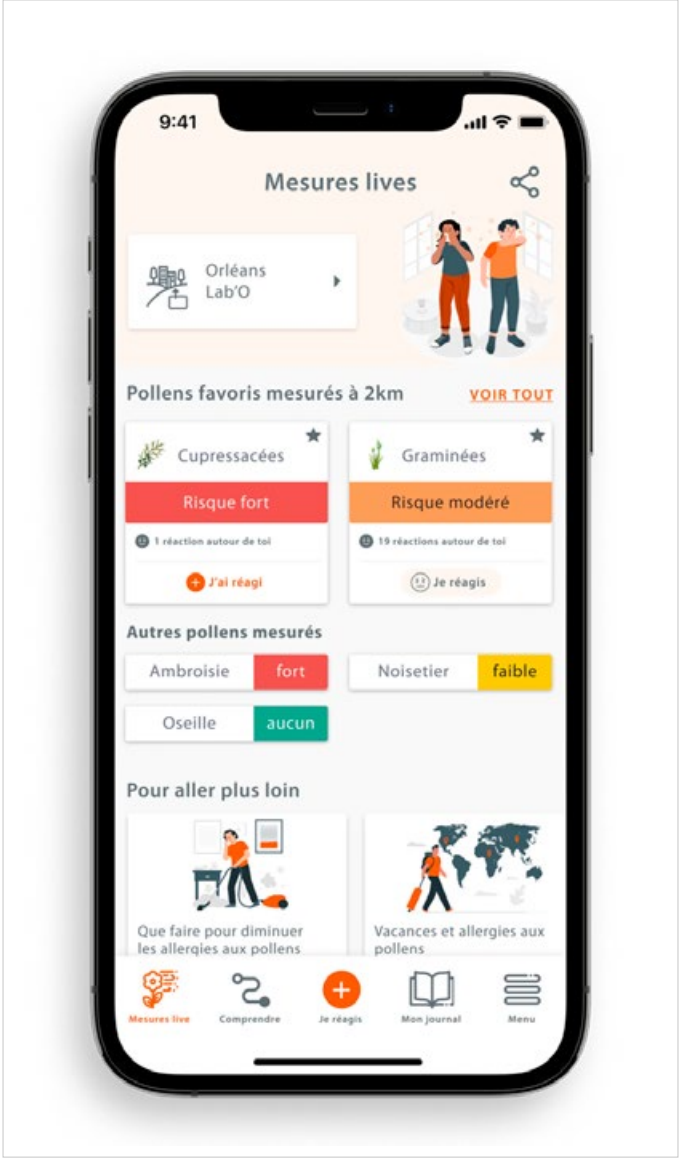
PRODUCTIVE SECTOR
Biomedicine and Health Care

More info

SS_041_2023

LIFY AIR

Change the lives of pollen allergy sufferers.



The Lify Air interface for pollen allergy prevention for more than 20 different pollens in France and Belgium.

PROBLEM DESCRIPTION

30% of the French population is concerned by pollen allergy, against only 3% in 1970, and the allergic population is predicted to pass the 50% mark in 2050. Taking treatment in advance significantly reduces allergic reactions. It is therefore crucial to provide pollen risk forecasts as early as possible.

CHALLENGES AND GOALS

- ✔ Pollenic risk forecasting.
- ✔ Multi-sources data fusion.

MATHEMATICAL AND COMPUTATIONAL METHODS

Lify Air designs and deploys optical sensors to measure the concentration of pollen in the air.

The objective is to provide forecasts fa allergy sufferers. Lify Air, Irisa and IRMAR collaboration has led to the development of statistical models for multivariate time series to combine meteorological information and optic signals for forecasting the pollen risks of about 20 species.

EU-MATHS-IN Success story

COMPANY
Lify Air

RESEARCH CENTRE
Institut de recherche mathématique de Rennes

PRODUCTIVE SECTOR
Biomedicine and Health Care

More info

SS_041_2023

LIFY AIR

Change the lives of pollen allergy sufferers.

RESULTS AND BENEFITS

Statistical models have been developed to combine historical pollen data, meteorology information and low level optic signals from the Lify Air sensors. Thanks to the models, Lify Air currently provide real time risk and will soon provide forecasted risk. 3 days in advance, for about 20 pollens. Risk indices are delivered via a personalized interface.

Space time statistical models for real time pollenic risk forecast.

Specific pollenic risk forecast at your location allows the reduction of allergic symptoms and side costs.

IRMAR & Irisa.

Lify Air, Orléans, France.

EU-MATHS-IN Success story

COMPANY
TwinSight

RESEARCH CENTRE
Centre national de la recherche scientifique (CNRS)

PRODUCTIVE SECTOR
Biomedicine and Health Care

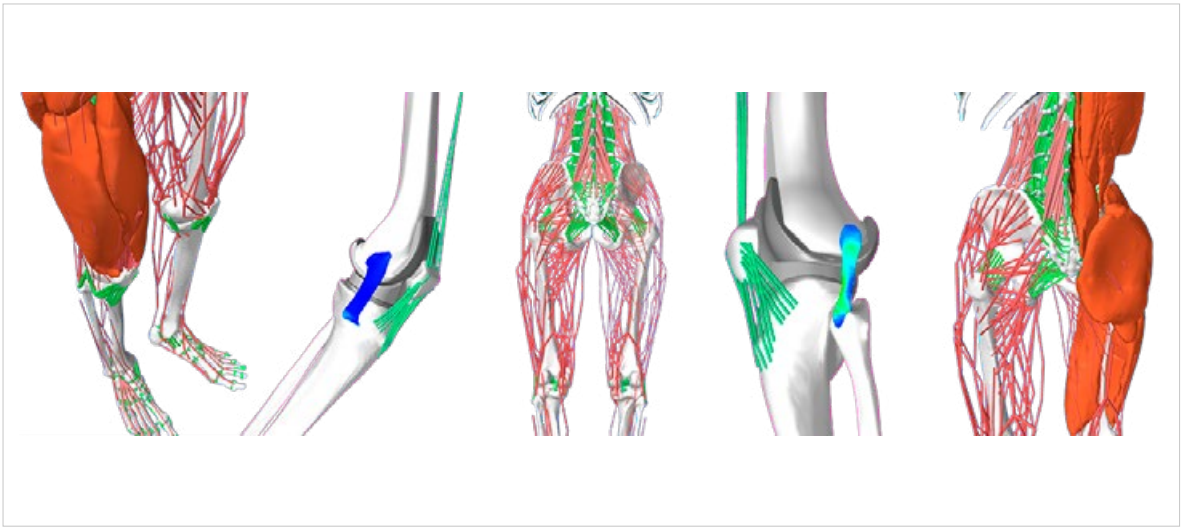
Digital Twin

More info

SS_040_2022

TWINSIGHT

Digital Orthopedic Twins.
Adaptive meshing for numerical simulation in biomechanics.



Patient-specific FE models of muscles and bones for orthopedic surgery.

PROBLEM DESCRIPTION

Automatic finite element (FE) meshing of anatomical structures based on medical images is a complex procedure. The resulting meshes can produce inaccurate solutions due to the poor shape of some cells or a poor mesh resolution in some regions.

CHALLENGES AND GOALS

- ✔ Quantifying the discretization error
- ✔ 3D meshes from complex anatomical structures
- ✔ Sophisticated mathematical models.

MATHEMATICAL AND COMPUTATIONAL METHODS

TwinSight creates accurate patient-specific numerical models for orthopedic surgery. These models are based on discretizations of anatomical structures from medical images, and use finite element analysis to predict the biomechanical behavior of bones and soft tissues.

These predictions are used by clinical staff to adjust therapeutic strategies, such as total knee replacement, so as to maximize functional performance and patient satisfaction. The TwinSight/CNRS collaboration aims at quantifying the error related to the discretization of the modeling domains and optimizing the mesh accordingly. This approach ensures that the numerical results are reliable while reducing the computational cost. The underlying mathematical tools used in the project are related to goal oriented a posteriori error estimates.

EU-MATHS-IN
Success story

COMPANY
TwinSight

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Biomedicine and Health Care

Digital Twin

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SS_040_2022

TWINSIGHT

Digital Orthopedic Twins.
Adaptive meshing for numerical simulation in biomechanics.

RESULTS AND BENEFITS

We have implemented goal oriented a posteriori error estimates for hyperelastic models of the soft tissue with active and passive constitutive laws. The underlying mathematical techniques form the cornerstone of the solution to the challenging modeling issue that the collaboration between TwinSight and the CNRS is tackling.

Biomechanical models with controlled error.

A significant advancement in the pipeline of numerical simulation which opens the way to more accurate and reliable patient-specific digital twins.

EU-MATHS-IN Success story

COMPANY
Microflown Technologies

RESEARCH CENTRE
ITMATI & Universidade da Coruña

PRODUCTIVE SECTOR
Mechanics and Mechatronics

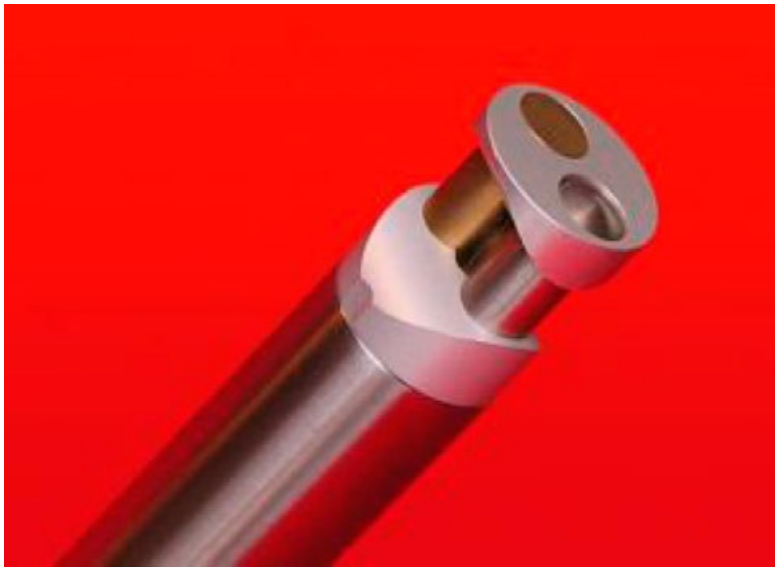
Digital Twin

More info

SS_039_2022

ACOUSTIC

Windshield designs for acoustic devices. Development and implementation of porous windshield designs for pressure-velocity sensors.



Pressure-velocity sensor produced by Microflown Technologies.

PROBLEM DESCRIPTION

The company Microflown Technologies was interested in the prediction and mitigation of the effects of airflow in its pressure-velocity sensors, and also in the design of porous windshields to avoid undesirable airflow phenomena.

CHALLENGES AND GOALS

- ✔ To guarantee the quality of the device measurements in the presence of wind.
- ✔ To increase the accuracy of measurements in windy outdoors.
- ✔ To identify accurately noise source locations under the presence of wind.

MATHEMATICAL AND COMPUTATIONAL METHODS

Firstly, the mathematical modeling of the pressure-velocity sensor and the windshield was written using a coupled problem which involve porous materials and a compressible fluid with an underlying flow. Second, a finite element analysis was performed to obtain an approximate solution of the particle velocity and the sound pressure. Both physical quantities were evaluated at the near and far field. All these information has been used to suggest and orientate the next-generation of pressure-velocity devices designed by the industrial partner.

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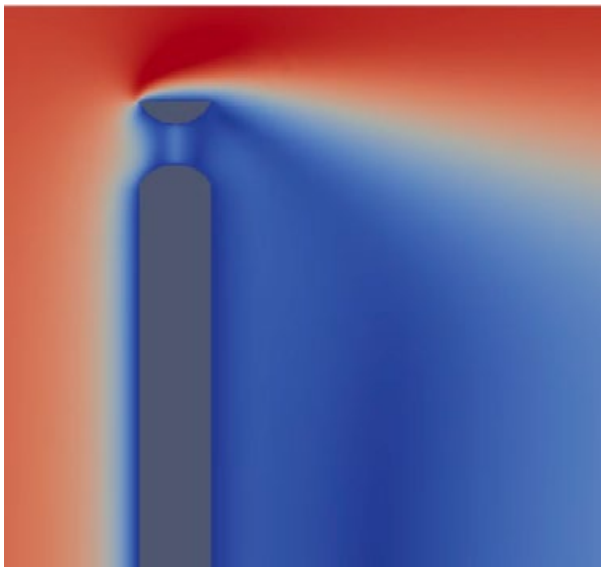
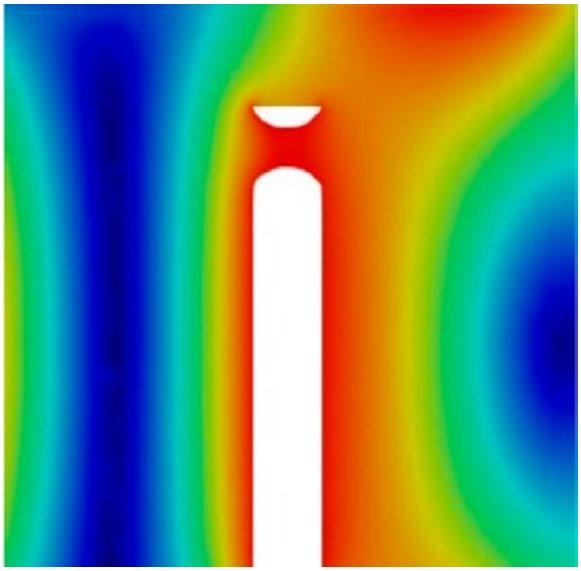


Numerical simulation of the airflow around the pressure-velocity sensor.



Numerical simulation of the scattered pressure field at 2000 Hz.

RESULTS AND BENEFITS

The development and deploy of a digital twin for the pressure-velocity sensor plays a key role of the design of the next-generation of acoustic devices. Thanks to this digital approach, the performance of different acoustic solutions based on porous windshields and micro-perforated steel meshes could be evaluated. Furthermore, the influence of the airflow on the device could be predicted at difference frequency ranges.

The company has a computational methodology to predict, design and optimize the acoustic behavior of its acoustic devices under the presence of an underlying airflow.

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ITMATI
UNIVERSIDADE DA CORUÑA
MICROFLOWN TECHNOLOGIES

ITMATI & Universidade da Coruña.

EU-MATHS-IN Success story

COMPANY
AFG Paris

RESEARCH CENTRE
Laboratoire de Mathématiques Appliquées du Havre

PRODUCTIVE SECTOR
Energy and Environment

Digital Twin

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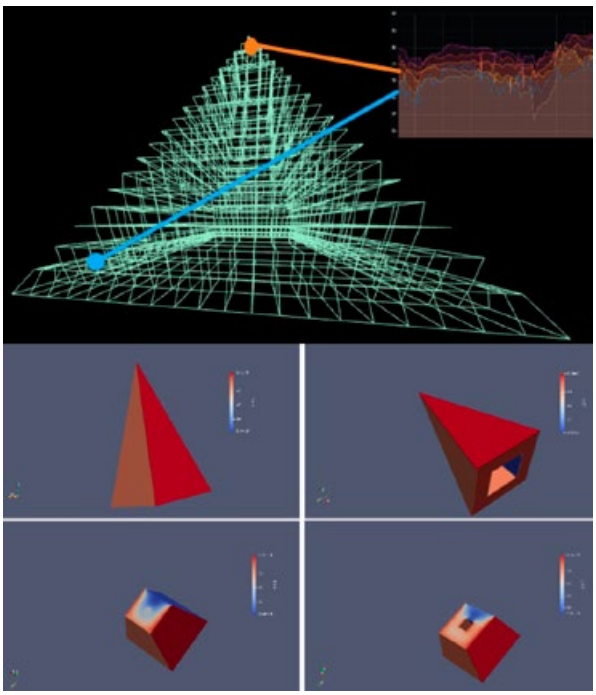
SS_038_2022

MTHC

Real Time Environmental Control. Modeling Temperature and Humidity in Complex buildings.



Numerical solutions of energetic fluxes with collected data from connected objects in a complex geometrical environment.

PROBLEM DESCRIPTION

Provide numerical solutions of temperature and humidity fluxes in 3 buildings with integration of connected data. Use of these solutions to control efficiently temperature and humidity.

CHALLENGES AND GOALS

- ✔ Integration of connected data in real time.
- ✔ Efficient numerical implementation.
- ✔ Energetic control and optimization in complex environment.

MATHEMATICAL AND COMPUTATIONAL METHODS

Mathematical solutions based on statistical treatment of data, dynamical systems and optimization.

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RESEARCH CENTRE
Laboratoire de Mathématiques Appliquées du Havre

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SS_038_2022

MTHC

Real Time Environmental Control. Modeling Temperature and Humidity in Complex buildings.

RESULTS AND BENEFITS

The collaboration allowed to collect a huge amount of data and compute solutions associated with the data and the physical geometry.

This opens the path to concrete optimized solutions for an efficient control of the energetic problem in buildings with complex geometry.

The methods can be generalized and extended to other problems.

More comfort and less cost.

Original mix of data collection in real time with connected objects, statistical and numerical implementation for optimized comfort with less energetic consumption.

Laboratoire de Mathématiques Appliquées du Havre.

COMPANY
Microgate

RESEARCH CENTRE
Johannes Kepler Universität Linz (JKU)

PRODUCTIVE SECTOR
Information and Communication Technology

Digital Twin

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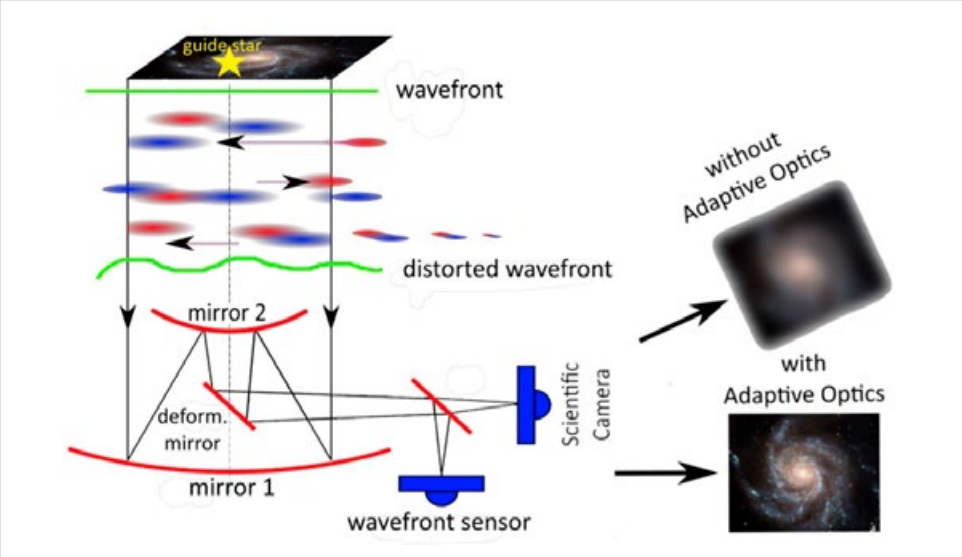
SS_037_2022

MICROGATE

Real-time computing methods for astronomical. Adaptive Optics. An iterative, wavelet-based real-time reconstructor for atmospheric tomography.



Basic design of an AO system.

The incoming, distorted wavefront reaches the deformable mirror and gets corrected.

A beam splitter splits the light into two parts. One part is propagated to the scientific camera and the other to the wavefront sensor.

The already corrected sensor measurements are used by a control algorithm to compute the deformable mirror commands for the next incoming wavefront.

PROBLEM DESCRIPTION

Astronomical imaging with ground based telescopes suffers from quickly varying optical distortions in the atmosphere. Sharpness and contrast of these images are essential for astronomical observations therefore, Adaptive Optics (AO) systems are applied. These systems are based on wavefront sensors, deformable mirrors and appropriate control algorithms.

CHALLENGES AND GOALS

Satisfying the demands on the AO system of the Extremely Large Telescope (ELT) of the European Southern Observatory is a challenging task In real time huge amounts of data have to be processed and thousands of actuators controlled by elaborated algorithms. Our project aims to develop and implement efficient control algorithms for the ELT first light instrument MAORY.

MATHEMATICAL AND COMPUTATIONAL METHODS

In our project we developed and implemented an efficient real time reconstruction algorithm for the ELT instrument MAORY on the high performance hardware of the industrial partner. Our algorithm, called Finite Element Wavelet Hybrid Algorithm (FEWHA), is a conjugate gradient (CG) based solver for atmospheric tomography. FEWHA utilizes a dual domain discretization strategy into a wavelet and finite element domain to obtain sparse operators. The matrix free representation of these operators leads to a significant reduction in the computational load and memory resources. Moreover, the method is highly parallelizable. We use preconditioning and an augmented Krylov subspace method in order to reduce the number of CG iterations.

COMPANY
Microgate

RESEARCH CENTRE
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PRODUCTIVE SECTOR
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SS_037_2022

MICROGATE

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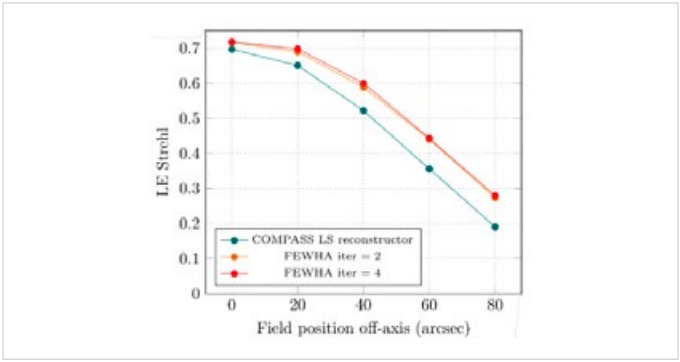
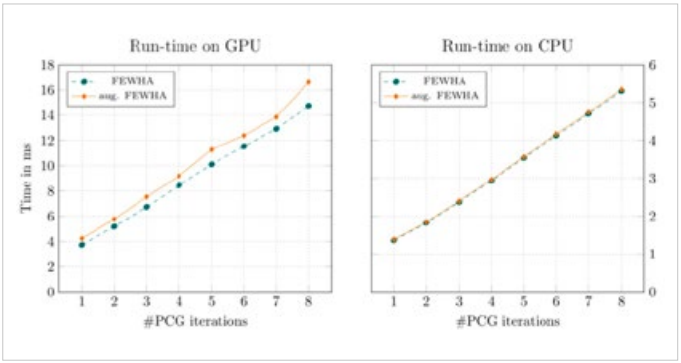


Quality verification.



Run-time analysis.

RESULTS AND BENEFITS

The main result of our project is an accurate and fast solver for atmospheric tomography optimized for the hardware of the industrial partner. The iterative real time reconstructor FEWHA is running in real time and provides an excellent reconstruction quality for the MAORY instrument. Microgate has benefited from the knowledge transfer on AO algorithms that can be used in further developments. Moreover, the company is able to extend its product portfolio and provide a package including efficient hardware and software for the real time control of AO systems, not limited to astronomy applications.

An efficient real-time reconstructor for large AO systems implemented and optimized for Microgate's AO control hardware

COMPANY
CIC Energigune

RESEARCH CENTRE
BCAM (Basque Center for Applied Mathematics)

PRODUCTIVE SECTOR
Energy and Environment

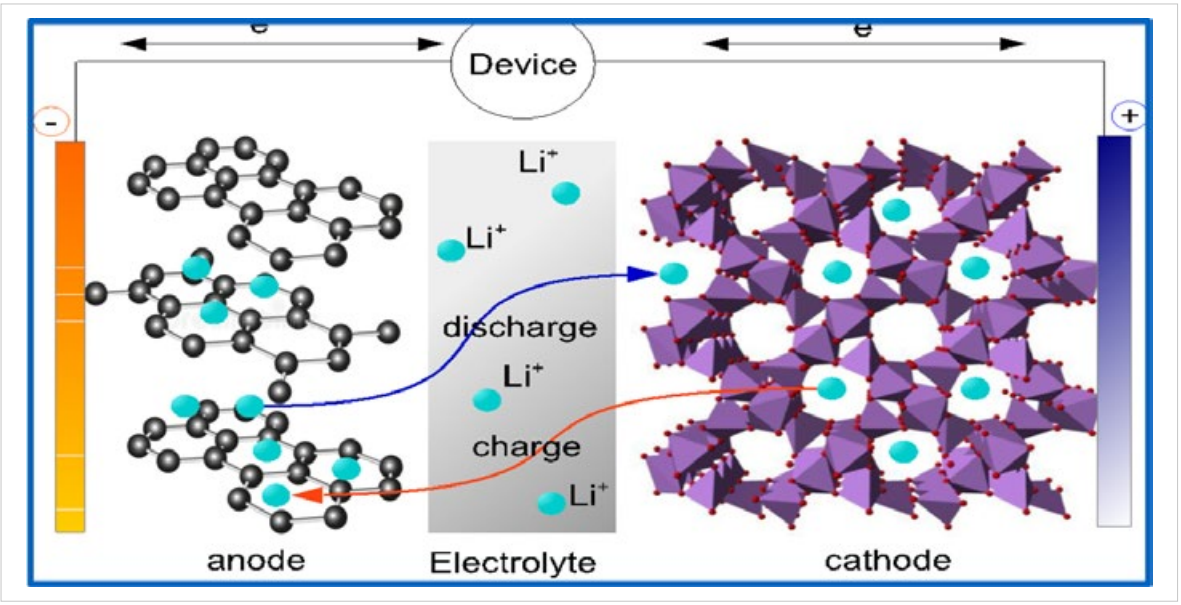
Digital Twin

More info

SS_036_2022

CIC ENERGIGUNE

Using Multiscale Simulations to Develop Advanced Battery Materials.



The multiscale and multiphase structure of the electrochemical cell in a LIB. Each LIB consists of an anode and a cathode separated by an electrolyte containing dissociated lithium salts, which enables transfer of lithium ions between the two electrodes.

PROBLEM DESCRIPTION

Lithium-ion batteries (LIBs) have triggered a revolution in portable electronics that has transformed our lifestyle. The steady increase in energy density is allowing the disrupting technology of electric vehicles (EVs), which can potentially enable a future of clean and sustainable human mobility. To reach such lofty goal, it will be necessary to accelerate battery materials discovery by combining experiments with multiscale simulation schemes linking the quantum – atomistic – and mesoscale time and length-scales.

CHALLENGES AND GOALS

In collaboration with CIC energiGUNE, we aim to develop and apply novel computational strategies to understand the microscopic inner-workings of complex battery materials. We also seek to provide machine-learning based algorithms for optimizing their performance. Our greatest challenge involves incorporating quantum mechanical information into accurate atomistic and mesoscale models that run efficiently on typical parallel computing architectures.

MATHEMATICAL AND COMPUTATIONAL METHODS

We use a combination of density functional theory, molecular dynamics, and in-BCAM enhanced sampling techniques such as the generalized shadow hybrid Monte Carlo method, the mix & match Hamiltonian Monte Carlo method and adaptive multistage splitting integrators.

Our methodologies can be run on large-scale parallel computers and are proven to dramatically decrease equilibration times in the atomistic simulation of solid-state systems, while providing the dynamical information critical to assess the performance of battery materials.

COMPANY
CIC Energigune

RESEARCH CENTRE
BCAM (Basque Center for Applied Mathematics)

PRODUCTIVE SECTOR
Energy and Environment

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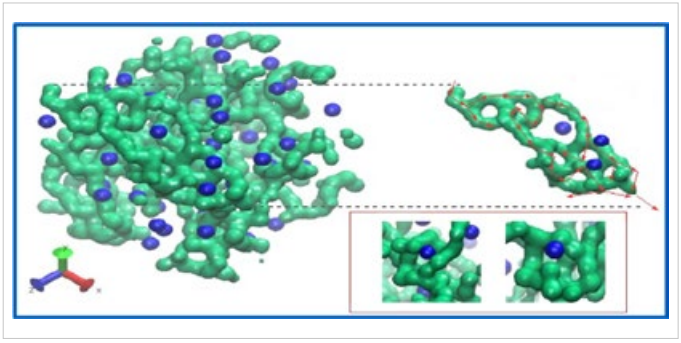
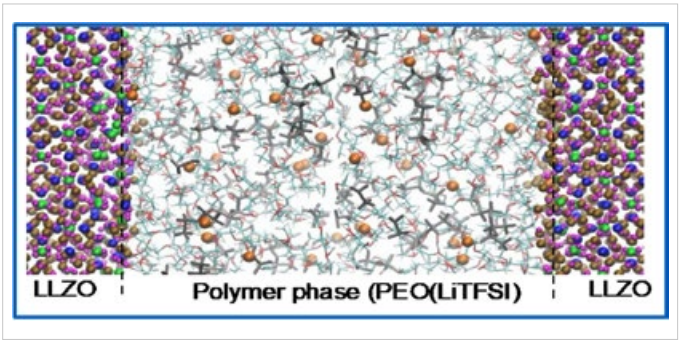
CIC ENERGIGUNE

Using Multiscale Simulations to Develop Advanced Battery Materials.



The trajectory of mobile Lithium ions around Ga substitutions in $L_{17}La_3Zr_2O_7$



Atomistic structure of composite PEO - $L_{17}La_3Zr_2O_7$

RESULTS AND BENEFITS

- ✔ Development of quantum-mechanical based force fields for revealing of mechanism of sodium diffusion in cathode material olivine $NaFePO_4$ for Sodium-ion batteries.
- ✔ Understanding how different doping strategies affect the performance of solid electrolyte materials, such as $Li_7La_3Zr_2O7$.
- ✔ Modelling the interfacial transport in composite polymer-ceramic solid-state electrolytes.r made software that, although being nowadays the core of the company ordering system, didn't imply any major changes on their existing ERP.

CIC energiGUNE has benefited from its collaboration with BCAM by incorporating atomistic simulations into their protocols for materials characterization. Considering their expertise in quantum mechanical modelling, this is a step further towards the building of multiscale schemes to accelerate the development of battery materials.

EU-MATHS-IN Success story

COMPANY
NORS Group

RESEARCH CENTRE
Laboratório de Engenharia Matemática do Instituto Superior de Engenharia do Porto

PRODUCTIVE SECTOR
Logistics and Transport

Digital Twin

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SS_035_2021

NORS

Price modelling on heavy-duty assitance contracts. Modelling, Simulation and Optimization of Assistance Contracts Cost's.

Graphic User Interface developed.

PROBLEM DESCRIPTION

Nors group is a Portuguese group whose vision is to be one of the world leaders in transport solutions and construction equipment. Given the high number of service contracts, the group needs an efficient way to analyze the existing data and to estimate the global cost of the assistance contracts, in order to minimize their risks.

CHALLENGES AND GOALS

- ✔ To evaluate the risk and price model that was implemented in the company.
- ✔ To construct a model that estimates the final cost of a contract.
- ✔ To guarantee a complete cost control through a fixed monthly fee.
- ✔ To implement the model through Graphic User Interface.

MATHEMATICAL AND COMPUTATIONAL METHODS

The developed methodology is based on probabilistic modelling of accumulated repair and maintenance costs. The probability density functions are chosen from a given set of known distributions or using kernel density estimators based on the minimization of the global error criteria.

Monte Carlo methods were used to simulate the total costs, based on the distributions of the random variables that represent the maintenance and the repair costs.

COMPANY
NORS Group

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Laboratório de Engenharia Matemática do Instituto Superior de Engenharia do Porto

PRODUCTIVE SECTOR
Logistics and Transport

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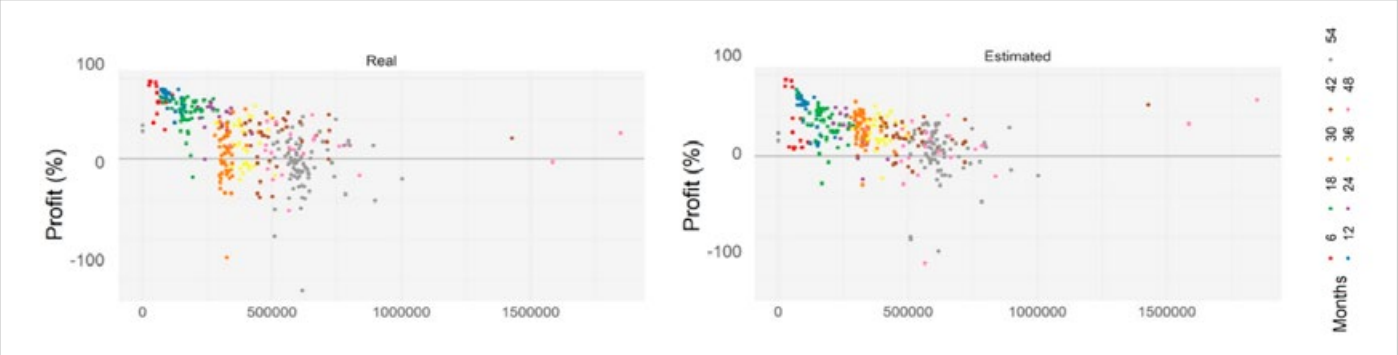
SS_035_2021

NORS

Price modelling on heavy-duty assitance contracts. Modelling, Simulation and Optimization of Assistance Contracts Cost's.



Real profit margins of a Nors Company versus mileage.

Estimated profit margins of a Nors Company versus mileage.

RESULTS AND BENEFITS

Contracts with a longer lifespan and more kilometers travelled tend to generate smaller profit margin and may even generate losses. Those contracts have much more variance on the cost's random variable, increasing significantly the company risk.

The developed mathematical model, materialized on a GUI, allows the business manager to estimate contract price proposals according to the model presented and to compare it with the ones that were previously settled by the company. The data processing also validates the parameters used to generate the assistance contracts quotations, checking their adherence with the company real costs.

The GUI that was implemented in the group allows the business manager to simulate contract prices considering different risk levels.

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NORS We Know How

Engineering Mathematical Lab.

EU-MATHS-IN
Success story

COMPANY
UmaniT

RESEARCH CENTRE
LMJL, Laboratoirede Mathématiques Jean Leray, Univ. Nantes & CHU de Nantes France

PRODUCTIVE SECTOR
Biomedecine and Health Care

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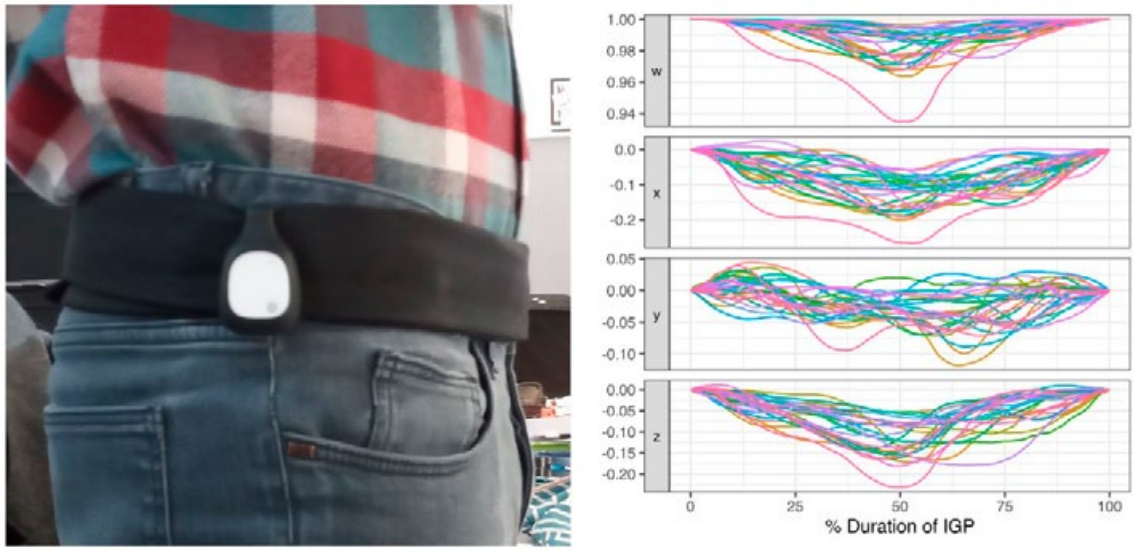
SS_034_2021

UMANIT

Daily-life gait impairment detection. Advanced statistical analyses at the service of gait-affected individuals.



eGait device and IGPs of 27 patients diagnosed with multiple sclerosis.

PROBLEM DESCRIPTION

Gait impairment comes with a major loss of autonomy, ultimately affecting the quality of life. Can we detect gait changes before symptoms appears so as to propose therapies to avoid or delay their occurrence?

CHALLENGES AND GOALS

- ✔ Measuring gait with a lightweight device tha individuals forget they are wearing to limit biases.
- ✔ Designing a biomarker called individual Gait Pattern, sensitive to changes in gait.

MATHEMATICAL AND COMPUTATIONAL METHODS

The main idea is to provide a so-called individual Gait Pattern (IGP) which describes the average rotation of the hip over time during a typical gait cycle. This is achieved using a tiny motion sensor, clipped on the right side of the belt, that records data to a secure server through a dedicated smartphone. The data comes in the form of a time series of unit quaternions. These are complex mathematical objects that motivated the development of specific statistical methods such as finding clusters of patients with similar gait impairment of designing risk indicators.

COMPANY
UmaniT

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LMJL, Laboratoirede Mathématiques Jean Leray, Univ. Nantes & CHU de Nantes France

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SS_034_2021

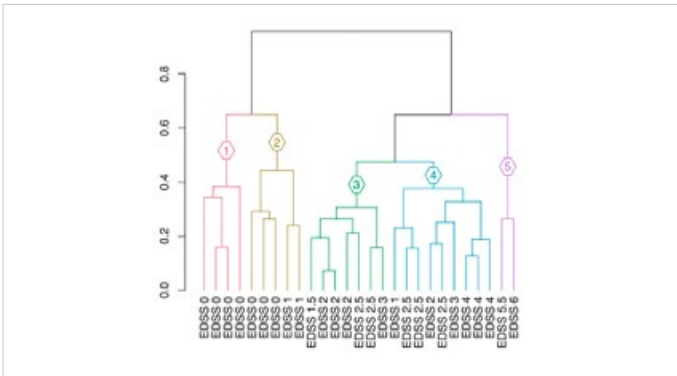
UMANIT

Daily-life gait impairment detection. Advanced statistical analyses at the service of gait-affected individuals.

RESULTS AND BENEFITS

We analysed and clustered the IGP of 27 patients diagnosed with multiple sclerosis, Cluster 1 regroups patients with no clinical evidence of gait impairment only, while Cluster 2 regroups patients with mild walking deficiency. This suggests that the IGP detects clinically-invisible gait differences.

In the long term, the proposed device should help clinicians to assess gait impairment, in daily life, for patient suffering with any gait-affecting disorder.



LMJL, Laboratoire de Mathématiques Jean Leray, Univ. Nantes & CHU de Nantes France.

COMPANY
CIE Galfor

RESEARCH CENTRE
ITMATI & USC

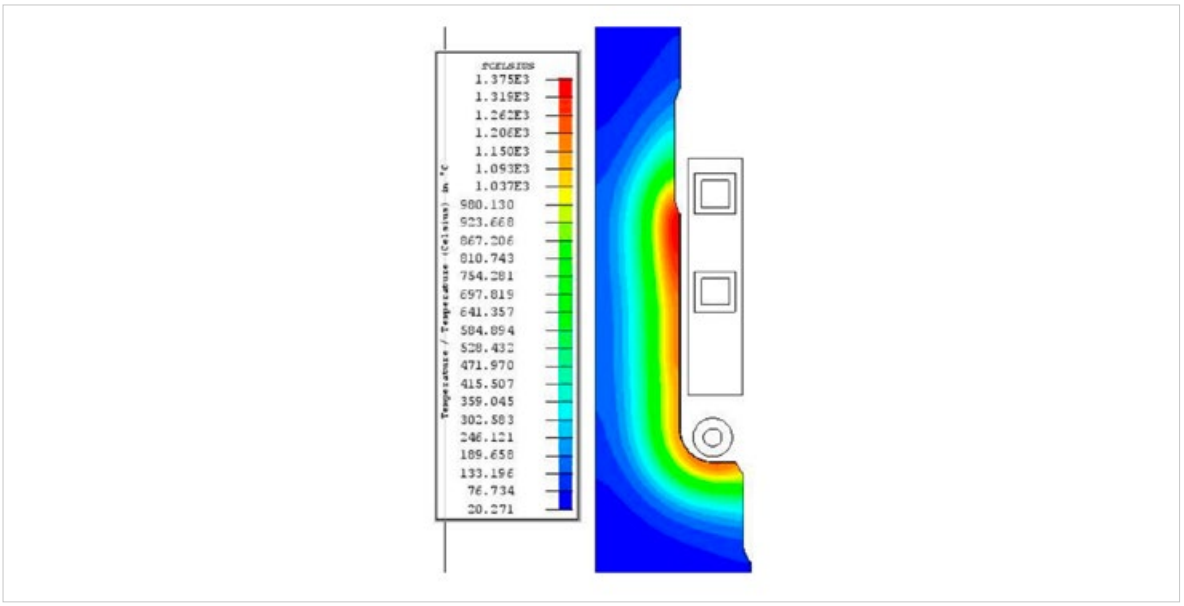
PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

SS_033_2021

TEINEXT

Numerical simulation of induction hardening of ferromagnetic parts.



Temperature of the piece in the area of interest at the end of the process.

PROBLEM DESCRIPTION

Mathematical modeling and numerical simulation of the thermo-electromagnetic-metallurgical behavior of an inductor-part system during the heating stage.

CHALLENGES AND GOALS

- ✔ To develop a simulation tool allowing to calculate the electromagnetic fields and the induced currents on the part, the temperature profile along the time and the evolution of the different material phases during the heating cycle.
- ✔ To determine the influence on the results of geometric and operation parameters.
- ✔ To Predict, from the previous results, the inductor geometry that best suits the shape of the part to be hardened.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Mathematical modeling of coupled multiphysics phenomena.
- ✔ Partial differential equations, ordinary differential equations.
- ✔ Computational methods: finite element method (FEM), Newton's method, implicit Euler's method, curve fitting.
- ✔ Computer codes: Flux2D®, Code-Aster, FEniCS, Python.

COMPANY
CIE Galfor

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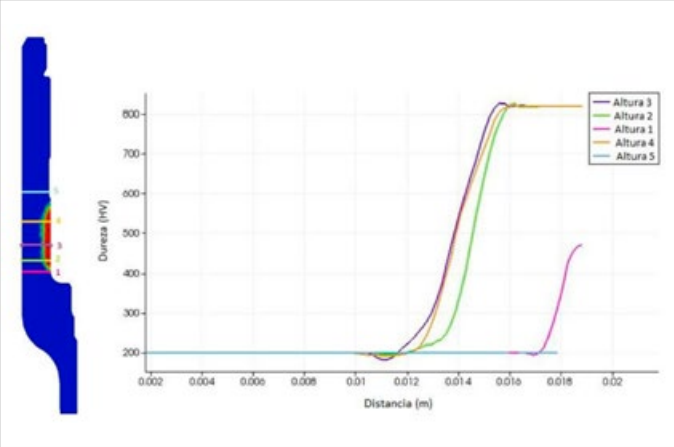
PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

SS_033_2021

TEINEXT

Numerical simulation of induction hardening of ferromagnetic parts.



Hardness at different heights in the area of interest of the part.

RESULTS AND BENEFITS

The numerical simulation is used as an innovation tool in the design process of induction hardening of ferromagnetic parts

Development of a free software tool that allows the numerical simulation of the process improving the performance and reliability of the system while reducing costs.

The numerical simulation will allow the company to improve the current design of the inductors and to evaluate new proposals with significant savings in costs and production time.

EU-MATHS-IN
Success story

COMPANY
COFRICO

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Food

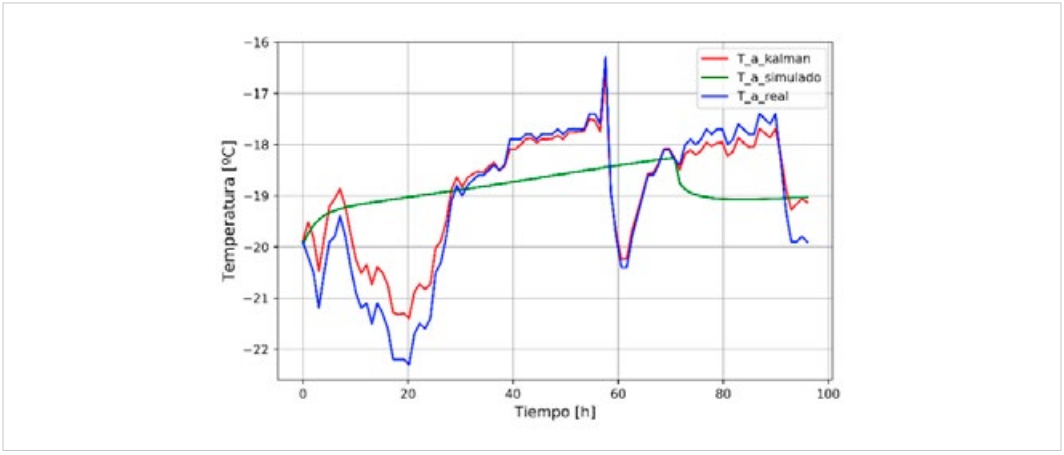
Digital Twin

More info

SS_032_2021

COFRICO

Modeling and Optimization of refrigeration facilities.



Air temperature of a single chamber: digital twin results with and without Kalman filter and measurements.

PROBLEM DESCRIPTION

Application of mathematical simulation, optimization, observation and control techniques to the improvement of refrigeration systems, which the COFRICO company designs, develops, executes and maintains.

CHALLENGES AND GOALS

- ✔ To develop a digital twin to simulate an industrial refrigeration system in which ammonia is used as a refrigerant fluid, building and solving numerically a mathematical model, based on physics and data, of the different elements that compose it.
- ✔ To optimize the operating conditions of an industrial refrigeration plant through the use of mathematical algorithms and establish the set point that allows this optimal operation.
- ✔ To develop a system for condition-based predictive maintenance, starting from an estimation of the health status of the system using Kalman filters and using the digital twin developed previously.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Ordinary and algebraic differential equations.
- ✔ Transient models of the whole refrigeration system.
- ✔ Determination of thermodynamic magnitudes of the refrigerant fluid.
- ✔ Digital twin of a refrigeration plant: simulation of the operation of the plant.
- ✔ Optimal control and predictive control of the installation: establishment of the set point that leads to the optimal operation of the installation.
- ✔ Condition-based predictive maintenance (CBM): use of the Kalman filter.
- ✔ Software: Python.

EU-MATHS-IN Success story

COMPANY
COFRICO

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Food

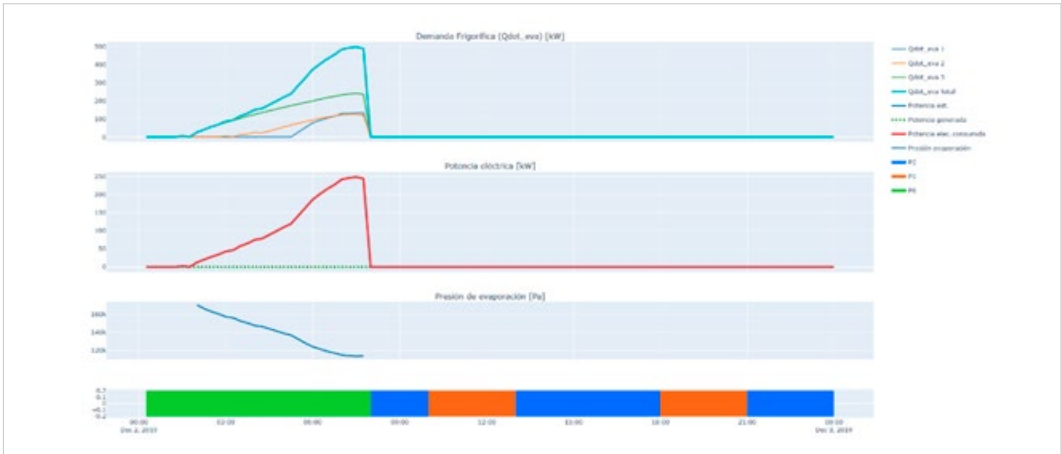
Digital Twin

More info

SS_032_2021

COFRICO

Modeling and Optimization of refrigeration facilities.



Set point provided by optimal control.

RESULTS AND BENEFITS

Improvement of the refrigeration systems, minimizing construction and operating costs, but at the same time respecting all requirements and guaranteeing food safety.

More efficient facilities are achieved, with lower operating costs and which also reduce their environmental impact, preserving food safety. The technological innovation that would be being introduced in this company and in the industrial refrigeration sector in general, would bring three improvements or competitive advantages: efficiency, cost reduction and reduction of environmental impact.

The application of mathematical simulation, optimization, observation and control techniques allow to achieve more efficient refrigeration facilities, with lower maintenance costs and which also reduce their environmental impact.

This project was co-funded by CDTI in the framework of PDI call.

EU-MATHS-IN Success story

COMPANY
WUJI&CO

RESEARCH CENTRE
LMA, UMR 7348, Poitiers

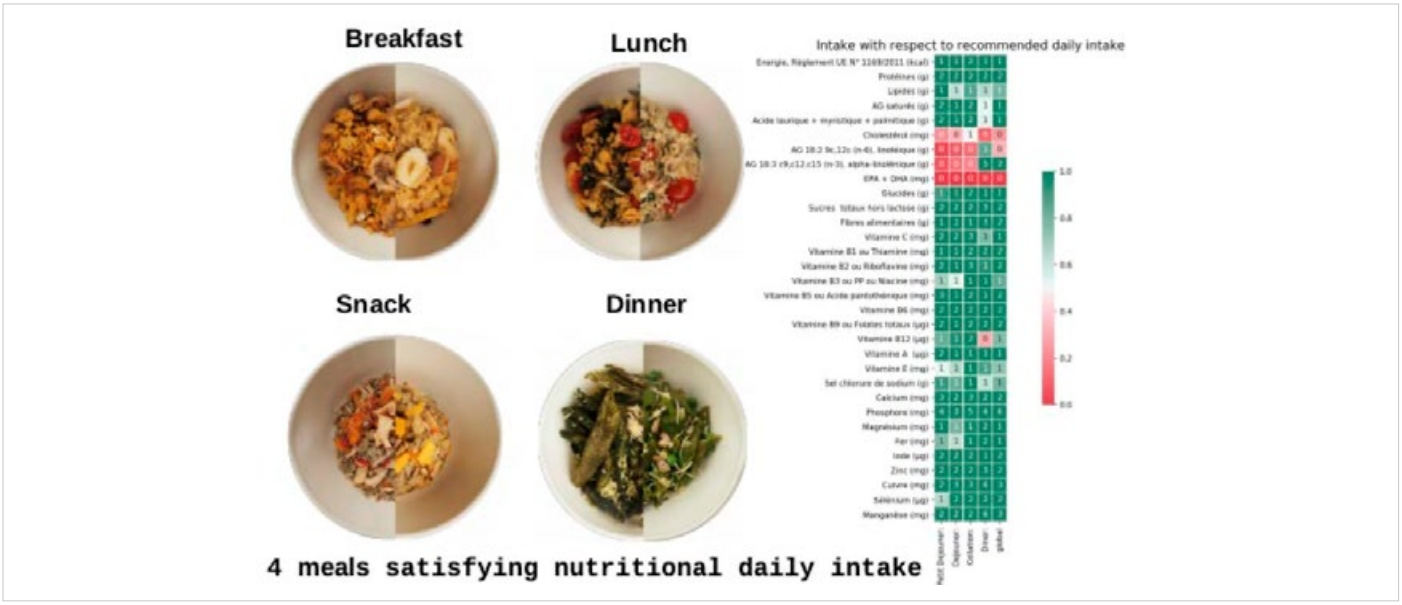
PRODUCTIVE SECTOR
Food

More info

SS_031_2021

WUJI&CO

HOX, mathematics for smart meals. Creation of healthy individualized meals.



PROBLEM DESCRIPTION

WUJI AND CO aims to conceive and produce (nutrient preserving) dehydrated tasty prepared meals. Set of meals should be formulated to satisfy individual specific needs.

CHALLENGES AND GOALS

- ✔ Maximize the satisfaction of heterogeneous nutritional targets during many days.
- ✔ While satisfying meals composition's rules; diversity; taste constraints; minimizing ingredients used.

MATHEMATICAL AND COMPUTATIONAL METHODS

The challenge is a multi-objective optimisation task with many nutritional constraints, as well as taste and sustainability of the production as additional constraints. Data are analysed and integrated. Several solutions for each specific nutritional profile are expected.

COMPANY
WUJI&CO

RESEARCH CENTRE
LMA, UMR 7348, Poitiers

PRODUCTIVE SECTOR
Food

More info

SS_031_2021

WUJI&CO

HOX, mathematics for smart meals. Creation of healthy individualized meals.

RESULTS AND BENEFITS

A modelling and technical framework based on stochastic algorithms was conceived and implemented as a prototype code able to design the expected recipes. Nutritional data were analysed and food-pairing networks were constituted. This work was jointly done with B. Coupier (post-doc) and E. Behar (intern, EFREI/d.school) supervised by P.-Y. Louis (LMA Poitiers).

Innovative framework and software for smart recipes formulation thanks to artificial intelligence methods and mathematical modelling.

Personalized healthy recipes.

EU-MATHS-IN
Success story

COMPANY
Proteopath GmbH
Bruker GmbH

RESEARCH CENTRE
Universität Bremen

PRODUCTIVE SECTOR
Biomedicine and Health Care

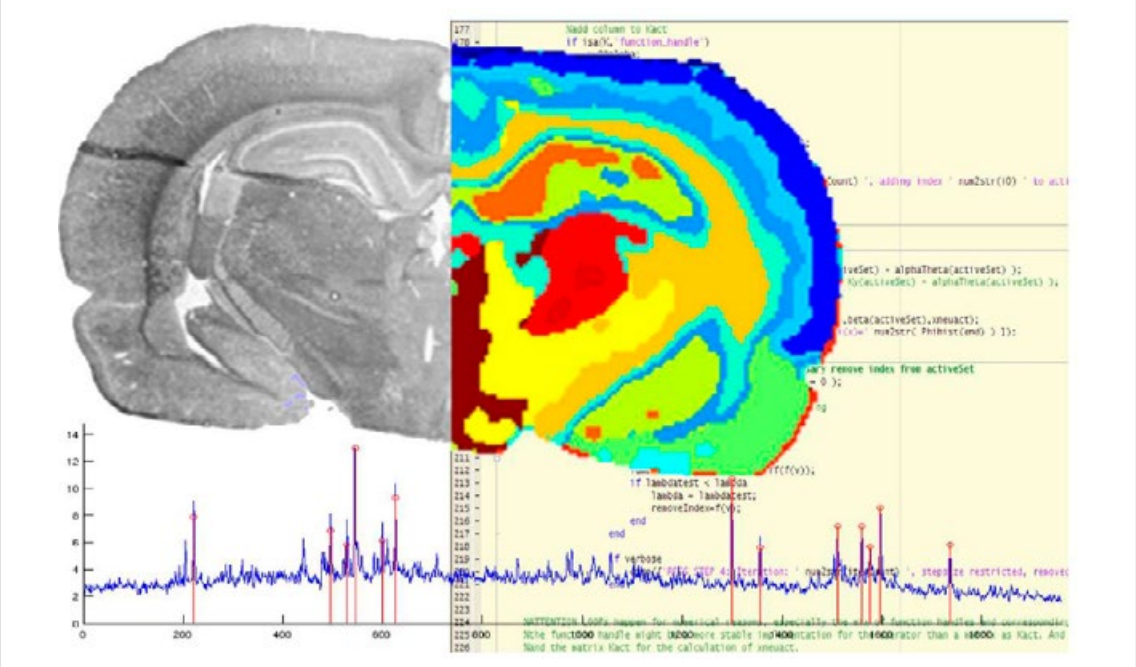
Digital Twin

More info

SS_030_2021

MALDI

Imagin exploring the molecular landscape. Machine learning approaches for blind source separation of high dimension mass spectrometry data.



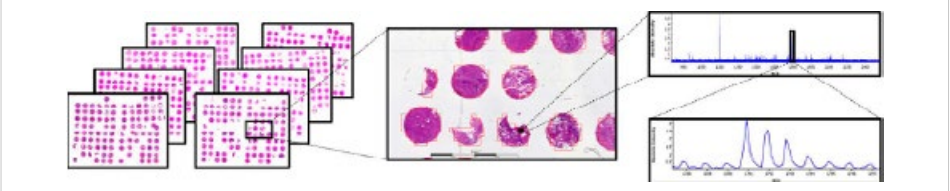
MALDI Imaging overview.

PROBLEM DESCRIPTION

Mass spectrometry imaging (MSI), in particular matrix-assisted laser desorption/ ionization time-of-flight (MALDI-TOF), is a label-free technique for spatially resolved molecular analysis of tissue samples with a broad range of applications in life sciences and biomedical research. It has become a routine technique for applications in drug discovery, biomarker detection or several Omics-methods. MSI, however produces extremely completely data sets, which cannot be evaluated without bioinformatics tools.

CHALLENGES AND GOALS

The success of MSI data analyses is based on a combination of technological hardware developments and the development of novel mathematical theories for extracting meaningful information. Data sets contain mass spectra, which are measured at different locations (pixels) of a tissue section. This yields a hyperspectral data set with thousands of channels (mass-to-charge values) at every pixel.



Schematic data structure. Optical images of hematoxylin/eosin stained TMAs (left), each with multiple core biopsies of lung cancer (middle). For each core several spectra are collected (upper right), close-up of an isotopic pattern for a peptide at m/z 1790.9 (lower right).

COMPANY
Proteopath GmbH
Bruker GmbH

RESEARCH CENTRE
Universität Bremen

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SS_030_2021

MALDI

Imagin exploring the molecular landscape.
Machine learning approaches for blind source separation of high dimension mass spectrometry data.

MATHEMATICAL AND COMPUTATIONAL METHODS

The mathematical algorithms used for MSI data analyses are based on theoretical research at the interface of functional analysis (inverse problems) and numerical linear algebra (matrix factorization). One important task is to determine characteristic spectral patterns in the data, which are the building blocks for classification schemes (e.g. in tumor typing) or identification (e.g. for biomarker detection).

RESULTS AND BENEFITS

The challenges and methods described are the core of the research activities of the Center for Industrial Mathematics (ZeTeM), University of Bremen, Germany. ZeTeM provided the mathematical foundations as well as – in collaboration with the national leading pathological service institute Proteopath GmbH in Trier, Germany – prototypical implementations for supporting pathological diagnosis. The resulting publications and patents were the basis for founding the spin-off company SCiLS GmbH, which developed a commercial software for analysing MSI data. This software has a market share of 80% worldwide and was acquired by Bruker Daltonics, the worldwide market leader in mass spectrometry imaging.

MALDI imaging has become a standard bioanalytic procedure in pharmaceutical and medical research.

Present developments aim at implementing MSI based procedures into clinical routine applications particular for supporting tumor diagnostics.

The mathematical methods described are relevant for the sort as well the long-term development of digital pathology.

EU MATHS IN
OpenDesk BY EU-MATHS-IN
Universität Bremen
PROTEOPATH
BRUKER

Proteopath GmbH, Trier, Germany
Bruker Daltonik GmbH, Bremen, Germany.

EU-MATHS-IN Success story

COMPANY
EKINNOX

RESEARCH CENTRE
Université Côte d'Azur & Inria

PRODUCTIVE SECTOR
Biomedicine and Health Care

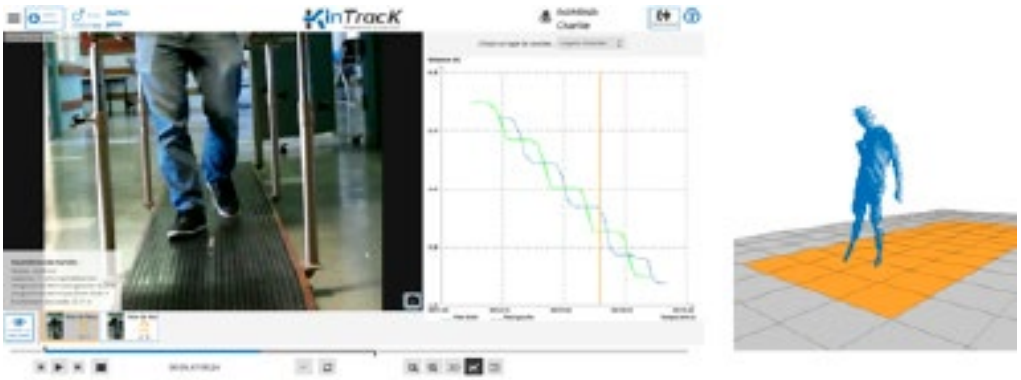
Digital Twin

More info

SS_029_2020

IPAM

Parametric Equations of Human Gait. Geometric Modeling of Human Walking for Medical Rehabilitation.



PROBLEM DESCRIPTION

An accurate and robust estimation of the trajectory of the foot is a crucial step in order to provide a reliable diagnosis assistance and a relevant monitoring of medical treatments.

CHALLENGES AND GOALS

Accurate and robust human gait parameters computation based on a single 3D camera within the context of physical rehabilitation. The goal is to provide an accessible and easy-to-use tool for caregivers to better evaluate, follow-up and improve patient performances.

MATHEMATICAL AND COMPUTATIONAL METHODS

A parametric continuous model of walking, based on Bézier curves, has been designed for representing the foot trajectory during walking.

A challenge was to find the right balance between the variability of the patients and the robustness to measurement uncertainties.

In a second step, we devised from this new parametric model an approximation/interpolation method in order to adjust its control parameters to datasets obtained from 3D camera acquisitions.

Finally, our accurate and robust method for estimating the locomotive walking parameters is used by physiotherapists from an instance of the model.

EU-MATHS-IN Success story

COMPANY
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Université Côte d'Azur & Inria

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SS_029_2020

IPAM

Parametric Equations of Human Gait. Geometric Modeling of Human Walking for Medical Rehabilitation.

RESULTS AND BENEFITS

The development and deploy of a digital twin for the pressure-velocity sensor plays a key role of the design of the next-generation of acoustic devices. Thanks to this digital approach, the performance of different acoustic solutions based on porous windshields and micro-perforated steel meshes could be evaluated. Furthermore, the influence of the airflow on the device could be predicted at difference frequency ranges.

A patented method implemented in a software used by physiotherapists.

A novel robust and accurate method for gait analysis to help caregivers in their diagnosis and treatments in physical rehabilitation.

COMPANY
Bekaert

RESEARCH CENTRE
KU Leuven. Department of Computer Science

PRODUCTIVE SECTOR
Materials

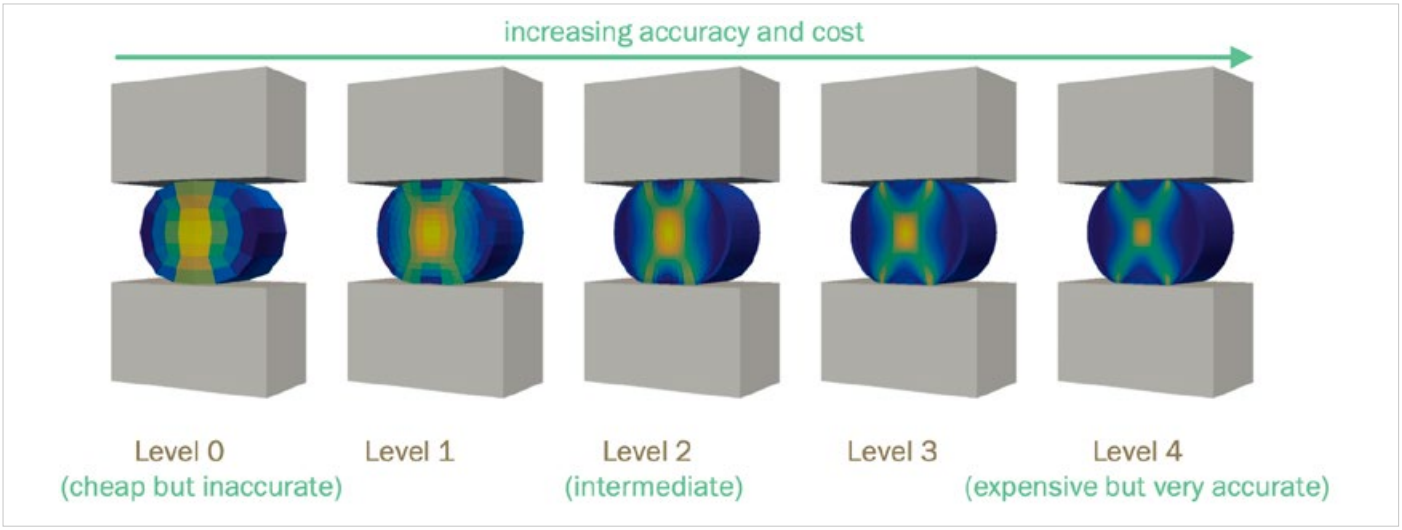
Digital Twin

More info

SS_028_2020

EUFORIA

Catching uncertainties in steel wire drawing. Multilevel Monte Carlo to the rescue.



PROBLEM DESCRIPTION

Bekaert is a world market and technology leader in steel wire transformation and coating technologies processing about 3 million tons of steel wire each year. To further increase the steel wire quality, Bekaert wants to reduce the various uncertainties in the wire drawing process using novel methodologies from uncertainty quantification (UQ).

CHALLENGES AND GOALS

- ✔ High dimensional: the presence of many uncertain parameters render classical UQ techniques impractical.
- ✔ Expensive simulations: a single simulation with fixed parameters takes several hours to even days.
- ✔ Industrial test case: not every parameter combination is feasible for the deterministic solver.

MATHEMATICAL AND COMPUTATIONAL METHODS

Wire drawing reduces the cross section of a steel wire by pulling it through a single (or a series of) drawing die(s). A mathematical model describes the non linear plastic deformation of the wire In this model, many uncertainties are present geometrical (wire diameter, wire shape), physical (wire strength, yield) and process related (approach angle, drawing speed).

Sampling techniques, such as Monte Carlo repeatedly pick random values for the uncertain parameters and evaluate the associated model output However, such techniques are too expensive to analyze the impact of uncertainties, since many model evaluations are needed.

Instead, a multilevel sampling strategy is used if the model is accessible on different levels of accuracy (e g by using different finite element grids), samples on different levels can be combined, such that many computationally cheap samples are taken on the coarse grid, and only few expensive samples are required on the finest grid.

COMPANY
Bekaert

RESEARCH CENTRE
KU Leuven. Department of Computer Science

PRODUCTIVE SECTOR
Materials

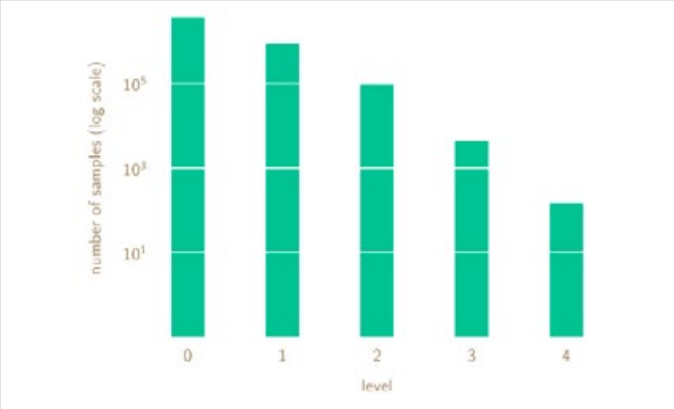
Digital Twin

More info

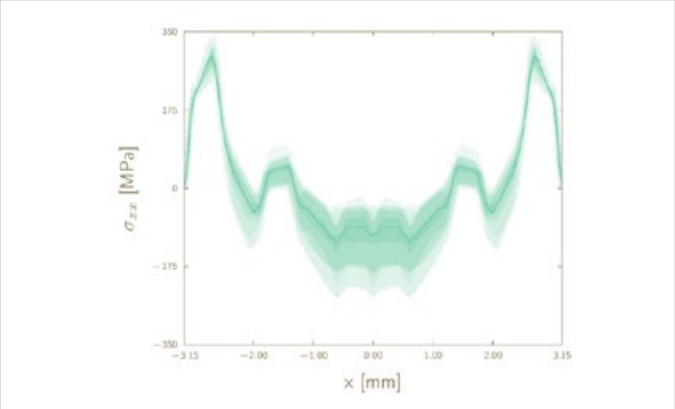
SS_028_2020

EUFORIA

Catching uncertainties in steel wire drawing. Multilevel Monte Carlo to the rescue.



Distribution of the number of samples across the levels



Example outcome: uncertainty on the tensile stress in a cross-section of the wire

RESULTS AND BENEFITS

Using the multilevel sampling approach, statistics of a quantity of interest can be computed much faster compared to previous UQ methods.

- ✔ Our Multilevel Monte Carlo method takes 12 days to compute the expected value of the drawing force (relative error of 1%).
- ✔ Our Multilevel Quasi-Monte Carlo method takes only 4 days.
- ✔ On the same hardware, classic Monte Carlo approach would take 1.5 years!

Using novel multilevel sampling techniques from uncertainty quantification that dramatically reduce the cost of a numerical simulation, the steel wire company Bekaert can produce steel wire with more reliable properties.

KU Leuven, Department of Computer Science, NUMA Section.

EU-MATHS-IN Success story

COMPANY
Neiker

RESEARCH CENTRE
Basque Center for Applied Mathematics (BCAM)

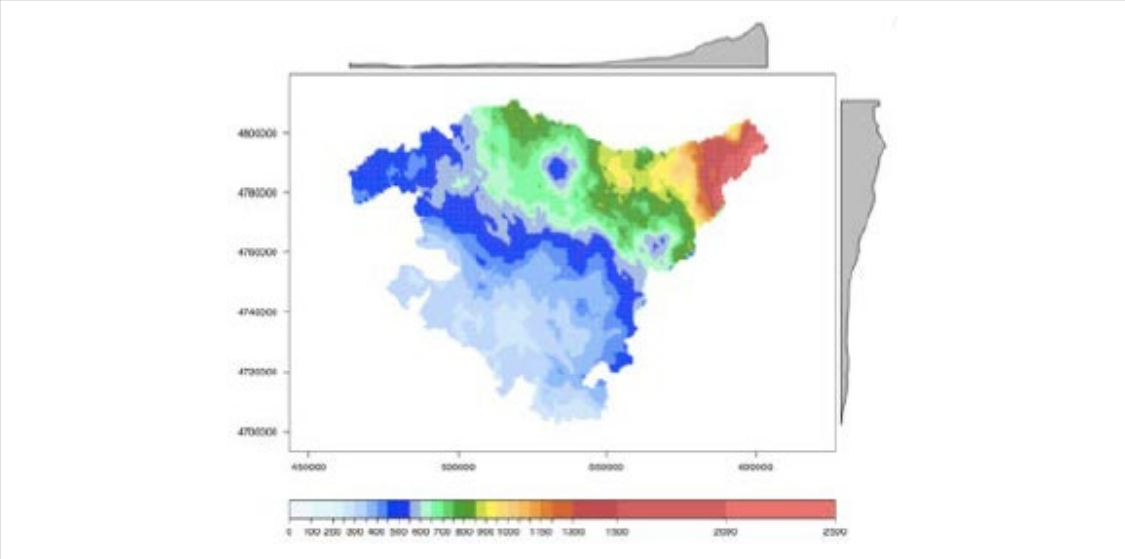
PRODUCTIVE SECTOR
Agriculture and Fishing

More info

SS_027_2020

NEIKER

Mapping high-resolution soil properties with geoadditive models.



Predicted R-factor Map.

PROBLEM DESCRIPTION

Neiker was interested in elaborating high-resolution maps of carbon stocks and soil texture properties in different land use at 0-30cm depth in the Basque Country.

CHALLENGES AND GOALS

The goals of the project were to compute the soil erosivity factor (R-factor) in MJ mm ha^{-1} h^{-1} yr^{-1} , to identify areas of susceptible erosion, to relate with climate and environmental variables, to predict organic carbon stock (Mg C/ha) and to predict soil texture properties (%sand, %clay and %silt).

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Geoadditive models are used as an unified framework for spatial prediction with smooth effects of climate variables such as average temperature, min/max temperature and precipitation.
- ✔ Carbon stocks are predicted using pedotransfer functions.
- ✔ Soil texture data are estimated using a compositional data approach using an additive log-ratio transformation and a multivariate Gaussian distribution.

COMPANY
Neiker

RESEARCH CENTRE
Basque Center for Applied Mathematics (BCAM)

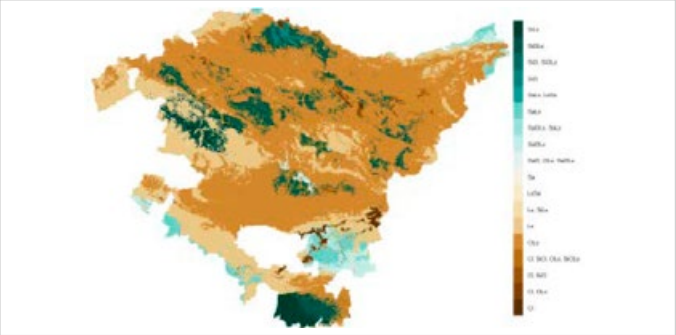
PRODUCTIVE SECTOR
Agriculture and Fishing

More info

SS_027_2020

NEIKER

Mapping high-resolution soil properties with geoadditive models.



Predicted soil texture map using USDA classification.

Predicted carbon stock map available at GeoEuskadi.

RESULTS AND BENEFITS

An unified mathematical framework for spatial prediction of rain erosivity factor and soil properties at high-resolution is developed.

These maps contribute to agricultural planning of crops, forest management and environmental protection.

Stock carbon and soil texture maps are publicly available at GeoEuskadi.

High-resolution maps of soil provide valuable information for the agricultural and forestry industry.

Basque Center for Applied Mathematics - BCAM.

EU-MATHS-IN
Success story

COMPANY
iAuditoria

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Food

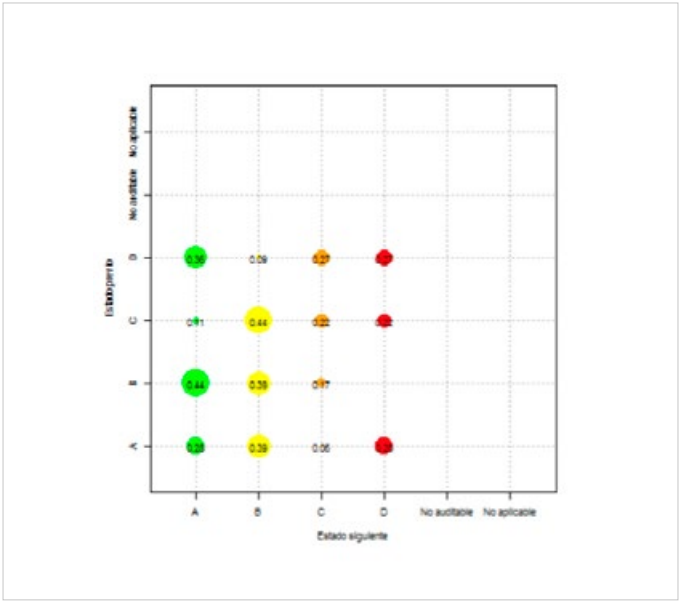
Digital Twin

More info

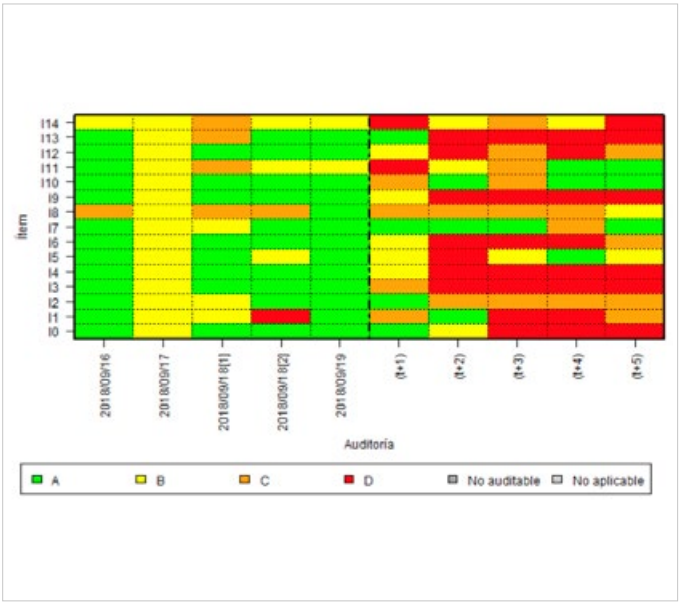
SS_026_2020

QUALITY IAUDITORIA

Validation of weighing, pattern development and predictive models in audits.



Estimated transition matrix from different audit results for a certain i tem.



Results of valuations by recorded audits.

PROBLEM DESCRIPTION

Analysis, design and implementation of adequate statistical methodology to respond to the improvement requirements of the ICT (Information and Communication Technologies) tool developed by the iAuditoria company in the performing of audits and / or inspections.

CHALLENGES AND GOALS

- ✔ Through the use of predictive models, value is added to the ICT tool, making it more attractive for potential iAuditoria clients.
- ✔ The iAuditoria's clients will be able to obtain statistical results on which to support their decision-making, based on their own history data or information from similar clients.

MATHEMATICAL AND COMPUTATIONAL METHODS

Use of Predictive models, to predict response variables from observations: univariate and multivariate Markov chains.

COMPANY
iAuditoria

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Food

Digital Twin

More info

SS_026_2020

QUALITY IAUDITORIA

Validation of weighing, pattern development and predictive models in audits.

Valuations of the items (by row) of each recorded audit (by column).

RESULTS AND BENEFITS

Increase the efficiency and improvement of the ICT tool.

Once an inspection and / or audit has been carried out, the application allows the generation of reports that, in addition to multimedia content, can include statistical results that allow iAuditoria clients to detect opportunities of improvement and anticipate possible risk situations.

In general, the results provided by these reports have been improved, which facilitates decision-making in the companies and client organizations of iAuditoria.

Value is added to the ICT tool, making it more attractive to potential iAuditoria clients.

Improve the efficiency of the ICT tool: Predictions (with uncertainty margin) for inspections and / or audits, which facilitates decision making.

EU-MATHS-IN Success story

COMPANY
FERROGLOBE. Advancing Materials Innovation

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Materials

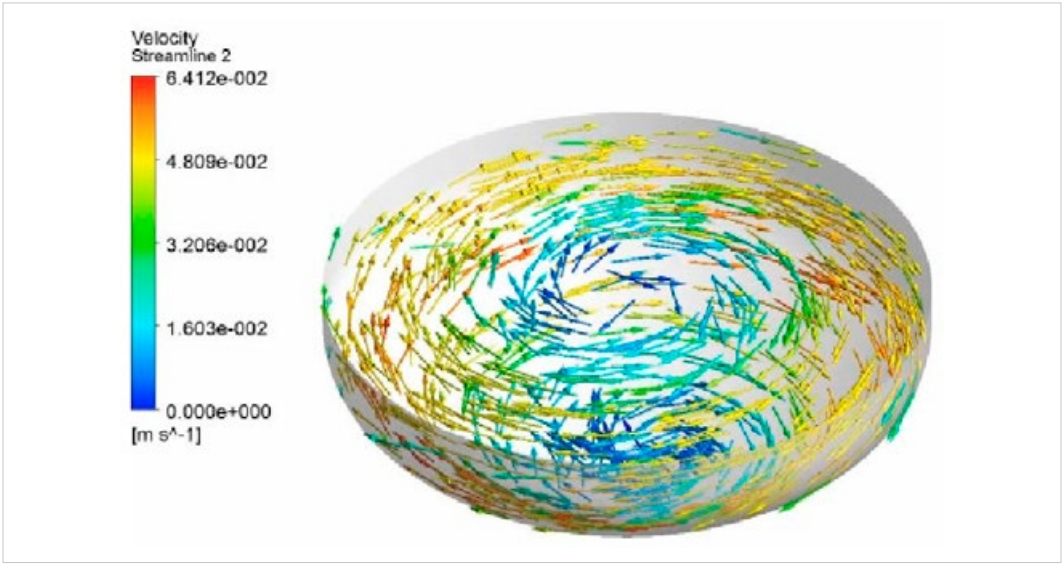
Digital Twin

More info

SS_025_2020

FERROGLOBE

Efficient Metal Purification Strategy. Industrial furnace for solar silicon purification.



Velocity field distribution in the motel metal.

PROBLEM DESCRIPTION

Mathematical modeling and numerical simulation with the aim of improving the efficiency and productivity of industrial furnaces for metal purification, thus allowing the treatment of greater quantities of material.

CHALLENGES AND GOALS

Study of an industrial furnace for solar silicon purification. The goal is to improve its efficiency and productivity through the integral numerical simulation of the coupled physical processes (electromagnetic, thermal, hydrodynamic, thermodynamic and structural) that take place inside it.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Mathematical Modelling of the multiphysics process: Non-linear partial differential equations: electromagnetism, heat transfer, hydrodynamics, gas kinetics, thermodynamics.
- ✔ Thermo-structural analysis of the key pieces of the furnace.
- ✔ Computational methods: finite elements, finite volumes, Newton's method.
- ✔ Commercial Codes: Flux3D, Ansys Fluent, Ansys Mechanical.

COMPANY
FERROGLOBE Advancing Materials Innovation

RESEARCH CENTRE
ITMATI & USC

PRODUCTIVE SECTOR
Materials

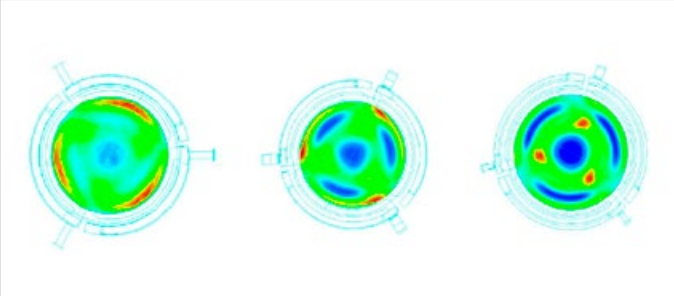
Digital Twin

More info

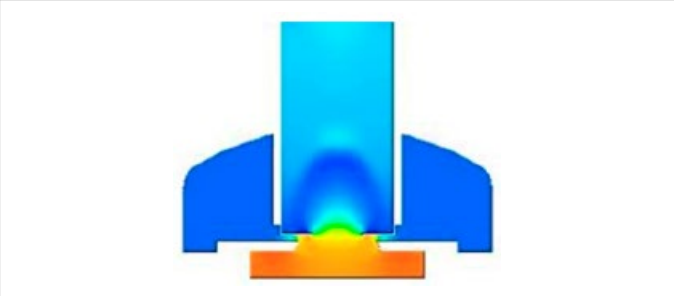
SS_025_2020

FERROGLOBE

Efficient Metal Purification Strategy. Industrial furnace for solar silicon purification.



Magnitude of the Lorentz's force (N/m^2) for different furnaces configurations.



Pressure field distribution In the pull chamber.

RESULTS AND BENEFITS

The company has been provided with a tool that allows it to control the behavior of the system, and to determinate the influence of the geometric and operating parameters in its performance, in order to optimize the process and avoiding trial-error tests in plant which are technically and economically very expensive.

The structural model has been added to the tool, and it allows to study with more detail parts of the machine under bigger thermal and mechanical stresses and to design alternatives without compromising the performance of the process.

Application of the model to furnaces of greater capacity, which allow to process greater quantities of material.

The numerical simulation has served the company to make a reliable estimation of the increase in power consumed by operating with larger machines without losing performance in the process.

On the basis of the results, the company was able to improve the design and operation of the solar silicon furnaces without the need to conduct costly and time consuming tests.

EU-MATHS-IN Success story

COMPANY
ECOMT

RESEARCH CENTRE
ITMATI & UVigo

PRODUCTIVE SECTOR
Energy and Environment

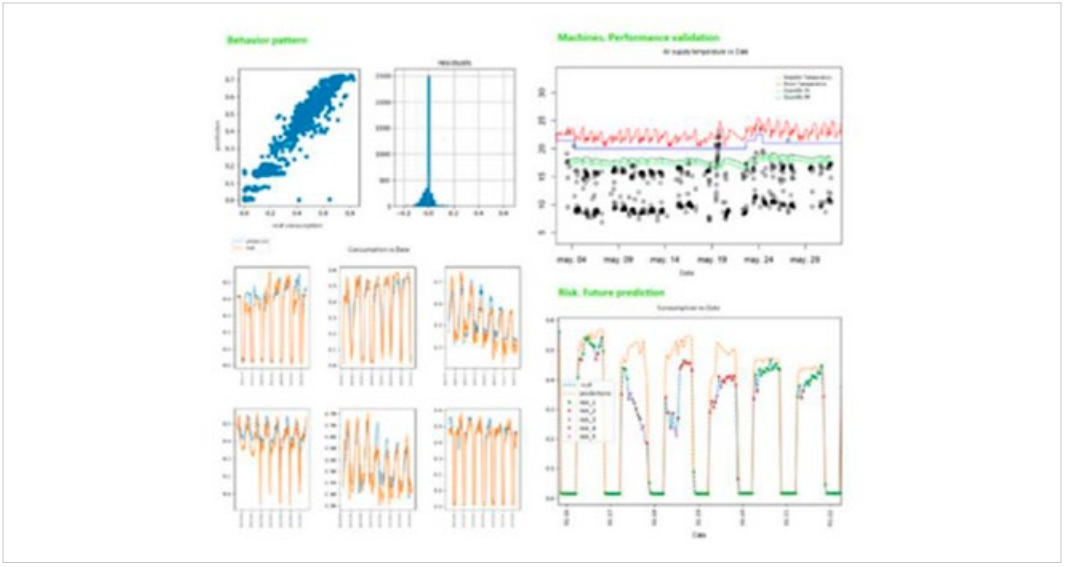
Digital Twin

More info

SS_024_2020

OTEARES

Improvement of the remote expert system based on software Otea.



Incidence prediction models based on ML and statistical techniques.

PROBLEM DESCRIPTION

Development of a system that, through the platform of remote management of facilities OTEA, is able to predict maintenance incidents through the interpretation of the data monitored, and can apply rules that improve the efficiency of the system and extend the life of the equipment.

CHALLENGES AND GOALS

- ✔ To multiply the value of the OTEA system by maximizing the efficiency of the facilities and minimizing the basic management resources.
- ✔ To deploy a predictive tool which enables to detect maintenance incidents before they happen.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Neural Networks.
- ✔ Random Forest.
- ✔ Quantile regression.
- ✔ Generalized additive models (GAM).

FORTISSIMO

This project was financed in the framework of the call: "Fortissimo 2 - Factories of the Future Resources, Technology, Infrastructure and Services for Simulation and Modeling 2", European Union's Horizon 2020 research and innovation.

EU-MATHS-IN
Success story

COMPANY
ECOMT

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SS_024_2020

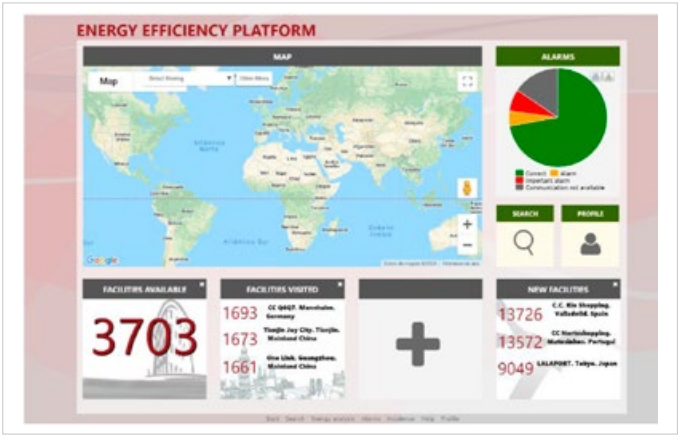
OTEARES

Improvement of the remote expert system based on software Otea.

RESULTS AND BENEFITS

The implemented tool created applies mathematical and statistical algorithms in order to get a reliable predictive maintenance, improving the efficiency of the current system, extending the equipment life cycle and allowing a smarter management of resources.

In addition, an increment of the OTEA platform value has been obtained, and offers a more complete service to the clients whereas the maintenance cost are reduced.



OTEA: controls, monitors and manages energy, synonymous of business intelligence.

OTEA enables decision support in real time offering a 24/7 service through itscontrol centre.

It is estimated an energy saving of 7% per installation, a reduction of 30% in preventive maintenance visits and a reduction of 20% in corrective maintenance.

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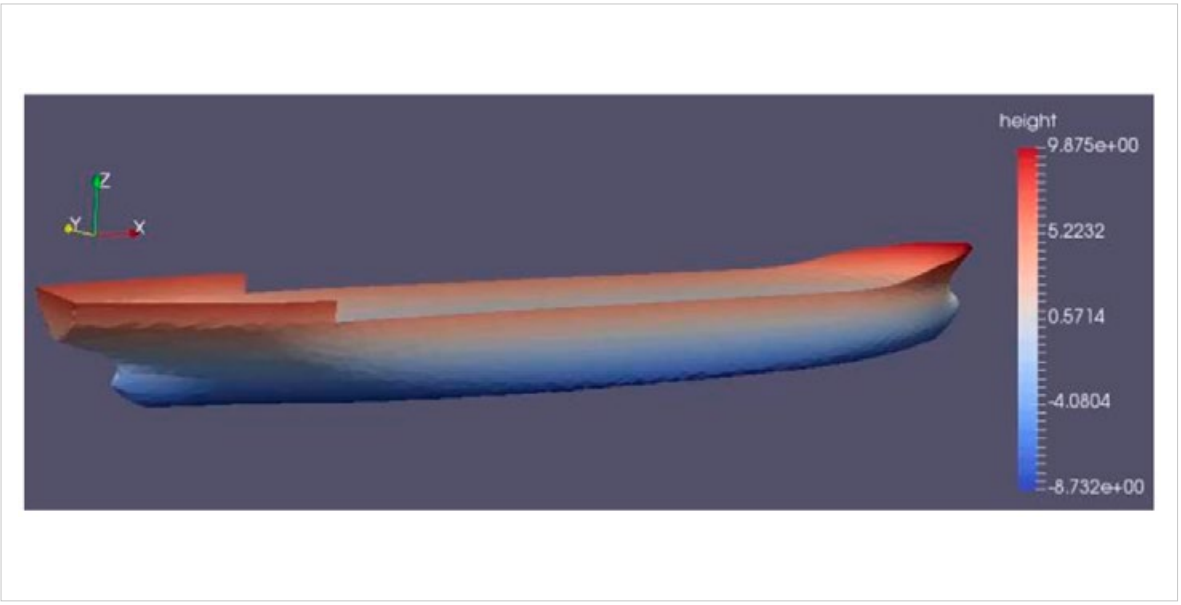
SS_023_2020

I4SEA

Dynamic draft study with constant environmental variables ShipFEM Code.



Height with respect to the sea free surface at the hydrostatic equilibrium position, plotted on the vessel hull.

PROBLEM DESCRIPTION

Development of a vessel draft prediction tool for the optimization of port management.

CHALLENGES AND GOALS

- ✔ Identification of the most relevant hydrodynamic phenomena under constant environmental conditions.
- ✔ Mathematical modelling of the hydrostatic and hydrodynamic problems and its numerical resolution to obtain the dynamic draft of a ship.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Hydrodynamic model: linear, incompressible fluids and use of velocity potentials.
- ✔ Physical problem with unbounded domain: PML technique (Perfectly Matched Layers).
- ✔ Computational domain: Automatic generation of geometries and meshes.

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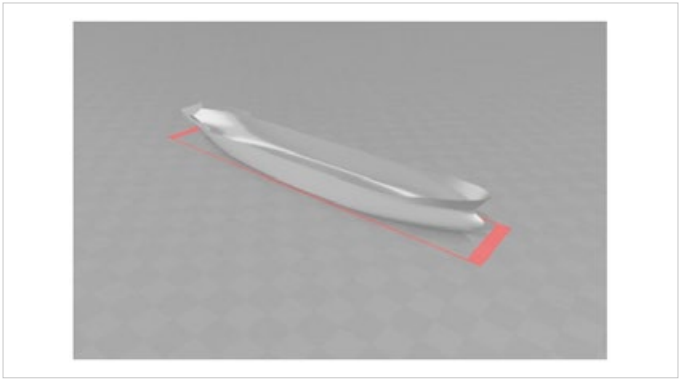

CAD model: geometry of the vessel hull.

RESULTS AND BENEFITS

- The computation of the dynamic draft using the ShipFEM code is efficient and accurate.
- This code has been included in the port consulting tool: i4cast.
- Its integration leads to a more complete and competitive tool in the market.
- An intelligent system that helps in making decisions through monitoring.
- Prediction of oceanic and climatic conditions.
- Simulation of the influence of environmental conditions on port operations in each vessel.

ShipFEM is an intelligent system that helps in making decisions through monitoring: prediction of the influence of environmental conditions on port operations in each vessel through simulation.

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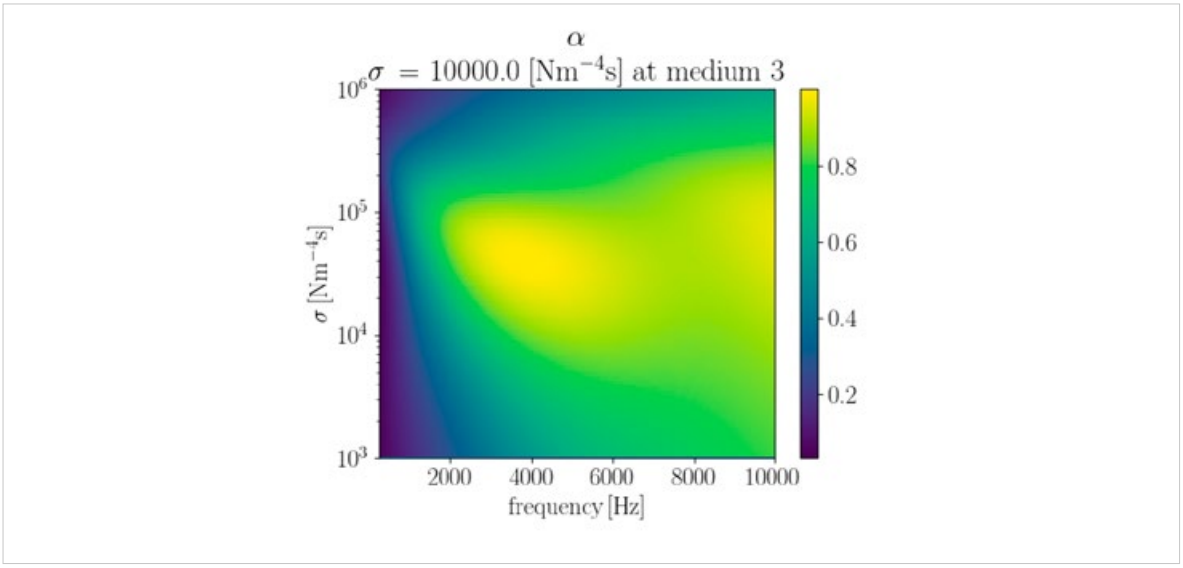
SS_022_2020

OPERPER

Mono and Multi-Component Polymeric Materials for Thermal and Acoustic Protection.



Absorption coefficient for a range of materials with different flow resistivity, where the frequency response is analyzed

PROBLEM DESCRIPTION

To obtain of a new kind of mono and multilayer materials for the automotive industry, which will be used to improve the comfort conditions inside the vehicle cabins.

CHALLENGES AND GOALS

- ✔ Development and verification of different specific mathematical and numerical tools to analyze vibro-acoustic and thermal problems involving a new range of polymeric multilayer materials.
- ✔ Optimization of the physical characteristics of mono and multilayer materials for the thermal and acoustic protection at low frequency range.

MATHEMATICAL AND COMPUTATIONAL METHODS

Acoustic problem: vibro-acoustic coupled models in one-dimensional structures.

Thermal problem: numerical simulation tool that allows, in a one-dimensional way, the thermal analysis of structures, and the post-processing of thermal variables of interest.

Finite element methods to solve the coupled three-dimensional vibro-acoustic problems in alpha cabins.

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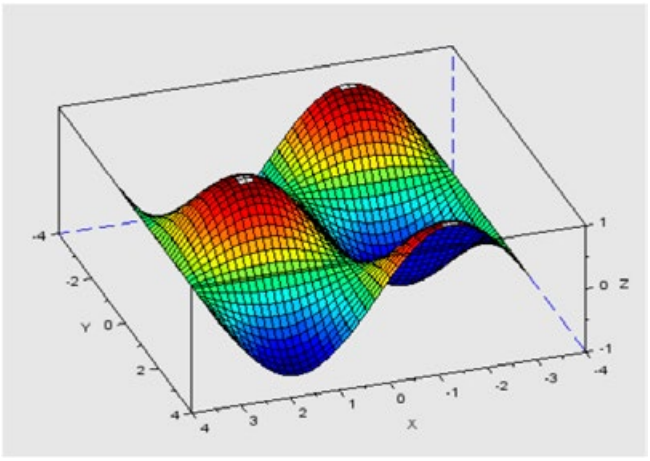
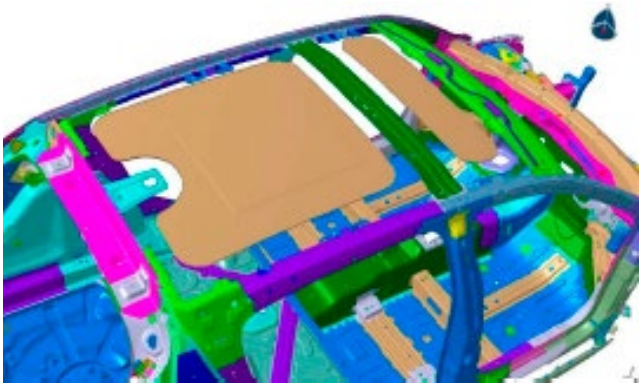


Graph generated by the developed OPERPER thermal tool



Parts with structural function: providing rigidity and damping to vehicle roofs

RESULTS AND BENEFITS

The numerical simulation is used as an innovation tool in the design process of multilayer materials.

Support to verify process parameters and to predict potential problems setting novel multilayer materials

Cost reduction by avoiding unexpected coupled phenomena, which could arise during the process of integrating layers of different materials.

Optimization of use of materials, energy consumption, and costs related to manufacture novel multilayer materials.

The numerical simulation allows to have a specific and complete range of fully qualified and quantified materials, so can offer specific solutions in terms of thermal and acoustic protection adjusted to different technical requirements.

EU-MATHS-IN Success story

COMPANY
McLLOYD

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Centre d'Analyse et de Mathématique Sociales (CAMS)
CNRS & EHESS (Paris)

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SS_021_2020

EQUINOMATH

Computing realistic imaginary races. Improving horses performance through tracking and optimization.

The data recorded by the McLloyd tracking device allow to live the race in virtual reality.

PROBLEM DESCRIPTION

McLloyd tracker provides accurate speed and position estimates of horses in a race. How these data could be useful to improve selection and training?

CHALLENGES AND GOALS

The aim is to provide a profile of the best strategy for a fixed distance, to understand the effects of changes in altitude and curves on the track. For each type of race, we determine the best horses profiles.

MATHEMATICAL AND COMPUTATIONAL METHODS

McLloyd's miniaturized tracker provides data on all the parameters of the horses running a race. Combined with two physics principles (energy conservation and Newton's second law), a solver compute the global optimal strategy for horses on a fixed distance. Small perturbations on the tracks (bending or slope) may lead to drastic changes on the optimal solutions. The race is then reconstructed in virtual reality and various combinations may be tested.

EU-MATHS-IN
Success story

COMPANY
McLLOYD

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SS_021_2020

EQUINOMATH

Computing realistic imaginary races. Improving horses performance through tracking and optimization.

RESULTS AND BENEFITS

Once we have the tracking data for a horse on a race, we compute realistic imaginary races on other tracks using optimization techniques. This should help to determine on which race to enter a horse. The project was supported by AMIES who allowed to hire an engineer.

The tracking device together with the mathematical model allow to improve races strategy and horse training.

Improve horses performance.

Centre d'Analyse et de Mathématique Sociales (CAMS) CNRS & EHESS (Paris).

EU-MATHS-IN
Success story

COMPANY
Hager

RESEARCH CENTRE
CEMOSIS.
Centre for modeling and simulation in Strasbourg

PRODUCTIVE SECTOR
Energy and Environment

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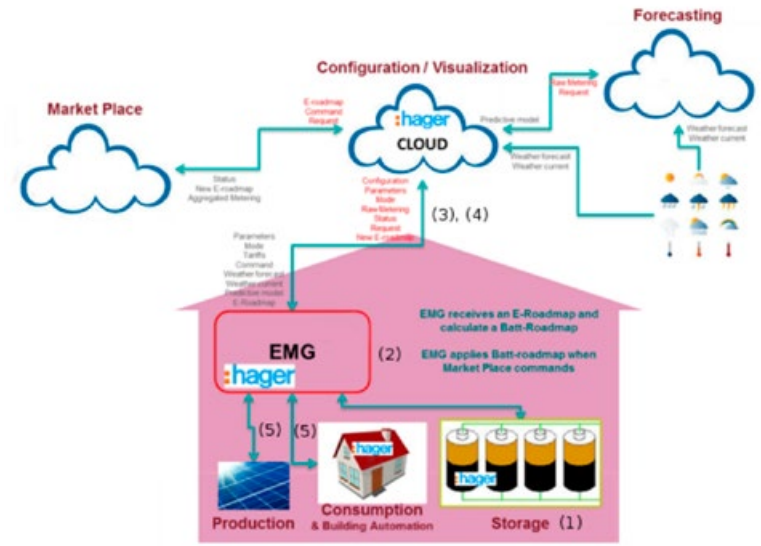
SS_020_2019

HAGER

M4SE Math for Smart Energy.
Optimization of energy storage within house holds.



PROBLEM DESCRIPTION

New problems emerged with the rise of photovoltaic panels, wind turbines and the ability to own its energy production: Network disturbances, regulated consumption in function of spot prices and waste of non- consumed or non-selled energy.

CHALLENGES AND GOALS

Control energy storage via energy buffers (batteries) and rejection in the electrical network with respect to distributors consigns (eroadmap)

Minimizing energy costs, maximizing energy resale during free schedule.

MATHEMATICAL AND COMPUTATIONAL METHODS

This project involves an optimization problem with constraints as wel as knowledges (predictive data):

- ✔ Minimize a cost function to fit the eroadmap in function of real energy production.
- ✔ Introduce constraints in the problem (Battery types, household production law imposed by governments).
- ✔ Add predictive data (weather prediction, house energy knowledges,...) in the model to handle free schedule.

EU-MATHS-IN Success story

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SS_020_2019

HAGER

M4SE Math for Smart Energy.
Optimization of energy storage within house holds.

RESULTS AND BENEFITS

A prototype algorithm has been proposed within a funding from AMIES (6 months) and a master internship.

Solving a blocking problem,it proposes a strategy to fit the eroadmap including predictive data.

The company implemented the patented algorithminits EMG controller for production.

Reduce energy waste, control consumption, optimize energy resale.

Energy storage to reduce energy wastes, guaranty safe electrical network for distributors, control energy resale for households.

COMPANY
ENGIE Green

RESEARCH CENTRE
INSA Rouen Normandie

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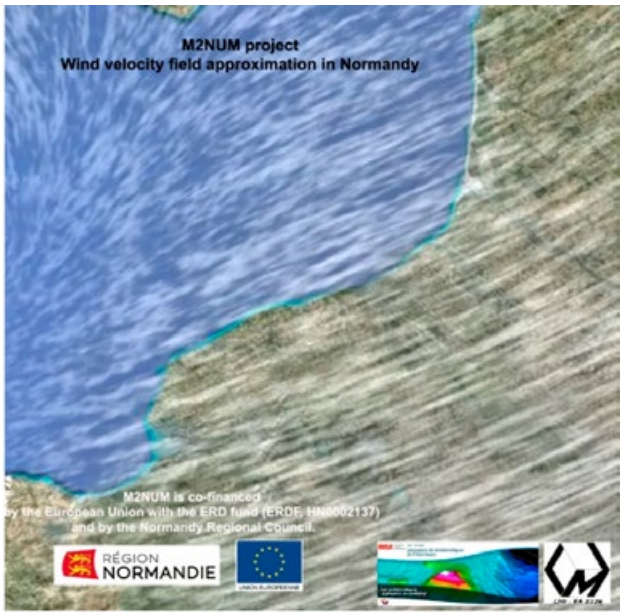
SS_019_2019

E@LIN

Wind velocity field approximation: Modelling and visualization on real datasets.



Numerical simulation in Normandy.

PROBLEM DESCRIPTION

Approximation of wind velocity field from sparse datasets, taking into account the topography, is a crucial step in order to build wind turbine farm.

CHALLENGES AND GOALS

- ✔ Regular approximation of the wind velocity field.
- ✔ Optimal visualization of the wind field simulation.

MATHEMATICAL AND COMPUTATIONAL METHODS

The problem of vector field approximation from sparse data emerges in a wide range of fields such as: motion control, computer vision, geometrical analysis, geometrical design, analysis of acoustic or electromagnetic waves, as well as in geophysics, medical imaging, fluid mechanics and so on... Many different approaches have been introduced to solve each specific problem occurring in the above fields of investigation to fit the vector field dataset. In this work, we use a regularized least-square problem defined on a space of potentials.

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Service Management

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SS_019_2019

E@LIN

Wind velocity field approximation: Modelling and visualization on real datasets.

RESULTS AND BENEFITS

We have developed cutting-edge technologies for rigorous wind velocity field approximation from sparse datasets.

The underlying mathematical techniques form the cornerstone of very challenging collaborations between LMI INSA Rouen and Energy industry.

A unique modelling and visualization algorithm for greening the economy.

Building new wind farms.

LMI, INSA Rouen Normandie, France.

EU-MATHS-IN Success story

COMPANY
Safety Line

RESEARCH CENTRE
Sorbonne Universités (UPMC)

PRODUCTIVE SECTOR
Logistics and Transport

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SS_018_2019

SAFETY LINE

Big data applied to air transport.
Risk estimation in air transport using machine learning.

PROBLEM DESCRIPTION

The data from airplane's flight recorders (black boxes) are stored by companies, but they remain unused, except when an incident occurs. Our idea is to detect risky situations from these data, even for an eventless flight.

CHALLENGES AND GOALS

Develop an algorithm to Detection of risky flights and to find variables which could be related to these risks. Propose a ready-to use implementation.

MATHEMATICAL AND COMPUTATIONAL METHODS

The aim of this work was to use machine learning techniques on flight data. The objective was to use a bottom-up strategy, starting from the question of finding flights which were potentially dangerous,even though though no accident occured. A first analysis indicates that data are highly dependent. Random forests were successfully applied to select relevant data from the events under consideration. This method was afterwards extended to multivariate functionnal data, allowing for the use of more general criteria.

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SS_018_2019

SAFETY LINE

Big data applied to air transport.
Risk estimation in air transport using machine learning.

RESULTS AND BENEFITS

The method proved to be efficient in several relevant use-cases. A software was developed, using this algorithm: FlightScanner. This software is now available as a product of the company.

The presented work was Baptiste Gregorutti PhD, supervised by G.Biau, B. Michel, and P. Saint-Pierre. Since then, B. Gregorutti has been hired as a researcher in data science then as a research manager.

New product allowing for efficient data analysis of flight data.

Use of up-to date machine learning algorithms in a risk management software.

EU-MATHS-IN Success story

COMPANY
Pollen Metrology

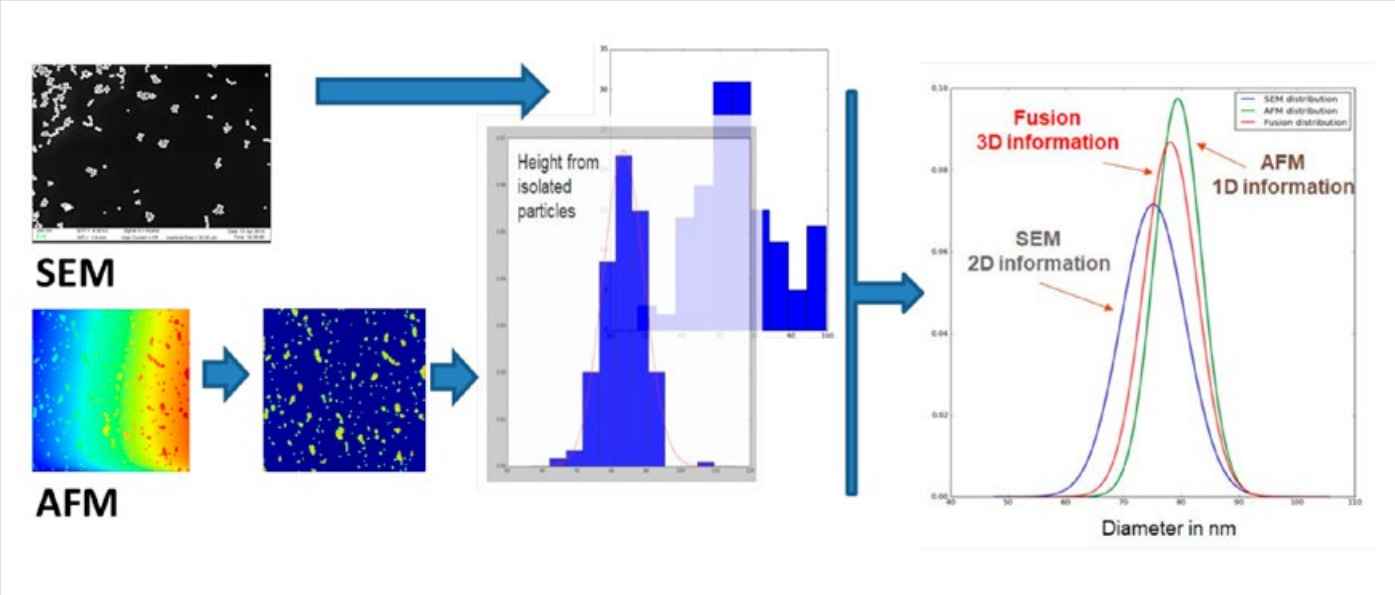
RESEARCH CENTRE
Laboratoire Jean Kuntzmann & MaiMoSiNe

PRODUCTIVE SECTOR
Electronics

SS_017_2019

POLLEN

Pollen Metrology: Data fusion for Metrology. Control and measurements of nanomaterials.



PROBLEM DESCRIPTION

By the 2000s, nanomaterial became industrial products, thus nanoprocesses need to be (nano)mastered. This means working on high density images / huge amount of data in an efficient way, i.e automated reliable, consistent and fast analysis.

CHALLENGES AND GOALS

- ✔ Getting workable images.
- ✔ Image analyzing.
- ✔ Data fusionning to extract the best results.

The process has to be fully automated and configurable for the end-user (client).

MATHEMATICAL AND COMPUTATIONAL METHODS

We choose appropriate computational methods from a selection of images types (Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy). As a preliminary step for classification, regions of interest are detected using SVMs techniques (Support Vector Machines) and SIFT descriptors (Scale Invariant Feature Transform). The following step, analysis of AFM images of nanoparticules, has been conducted in partnership with LNE (National Laboratory of Metrology and Testing) and was the object of a PhD thesis with UK Laboratory. Finally, data fusion is applied by aggregating statistical estimators to obtain the wanted characteristics of the material.

EU-MATHS-IN Success story

COMPANY
Pollen Metrology

RESEARCH CENTRE
Laboratoire Jean Kuntzmann & MaiMoSiNe

PRODUCTIVE SECTOR
Electronics

SS_017_2019

POLLEN

Pollen Metrology: Data fusion for Metrology. Control and measurements of nanomaterials.

RESULTS AND BENEFITS

Robust algorithms for preprocessing (removing trends, segmentation and detection) have been adapted and mixed with innovative data fusion methods.

- ✔ 99.9% success on LNE data for automated particle analysis and 100% of success for automated AFM flattening.
- ✔ Automated Fusion by combining two estimators coming from multiple measurement techniques.

Accurate 3D process control.

For end-users:

Higher production yield.

Time reduction from week to minutes!

Pollen:

Taking over of market share.

Recognised as innovative.

LJK & MaiMoSiNE, Grenoble, France.

COMPANY
RS2N

RESEARCH CENTRE
Math. Institute of Toulouse (IMT) and CNRS

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Energy and Environment

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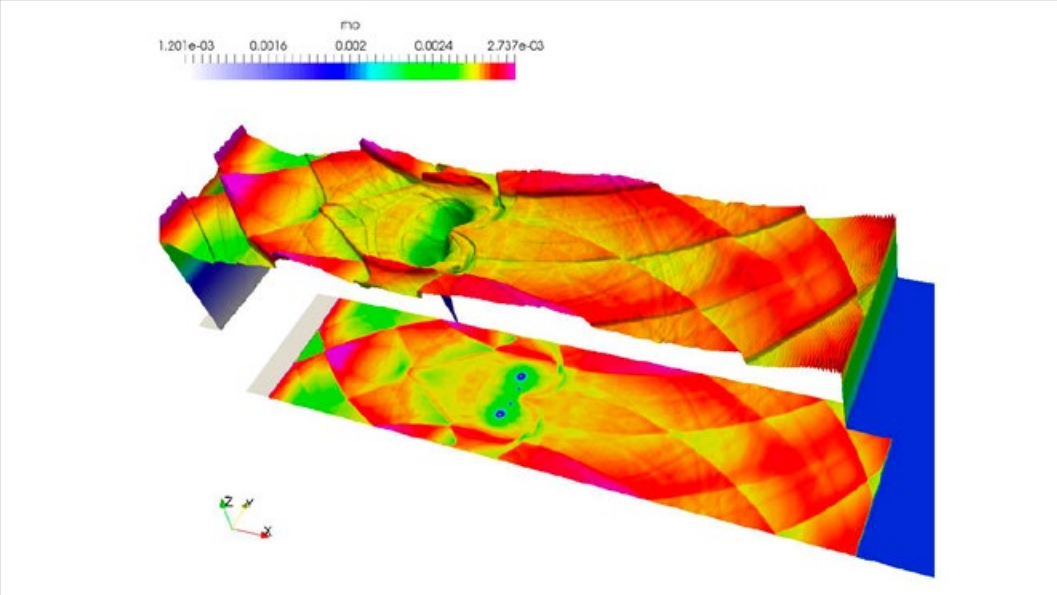
SS_016_2019

RS2N

Ultra Accurate Numerical Simulations. Heterogeneous and extreme high energy physics phenomena.



Detonation problem solved by a compressible hydrodynamics model involving heat release from chemical reactions

PROBLEM DESCRIPTION

Numerical simulations of extreme physical situations require large computational resources. Routinely on massively parallel computers, meshes of several millions of computational cells are used. Accuracy and efficiency shall constantly be improved.

CHALLENGES AND GOALS

- ✔ Star a long term collaboration between the private and academical partners.
- ✔ Improve the resolution capacity of algorithms implemented within numerical softwares.Control the number of efficient solutions determined and the time spent to get them.

MATHEMATICAL AND COMPUTATIONAL METHODS

To increase accuracy and efficiency, advanced and accurate numerical methods have been developed with firm mathematical basis. They allow to simulate of heterogeneous fluid flows encountered in extreme physical phenomena (detonation, shock, cavitation, phase changes). These recent developments reveals the genuine intimate structure of the flow.

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RS2N

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SS_016_2019

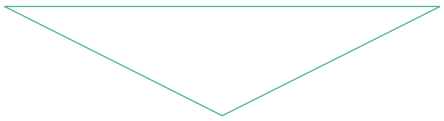
RS2N

Ultra Accurate Numerical Simulations. Heterogeneous and extreme high energy physics phenomena.

RESULTS AND BENEFITS

Enhance technological and mathematical transfers from academic scientific computation environment towards French private research laboratories developing simulation softwares for extreme and complex multi-physics phenomena.

Provides a significant advance in accuracy for numerical methods implemented in simulation softwares.



Capture of intimate flow structures.

Math. Institute of Toulouse (IMT) and CNRS.

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Success story

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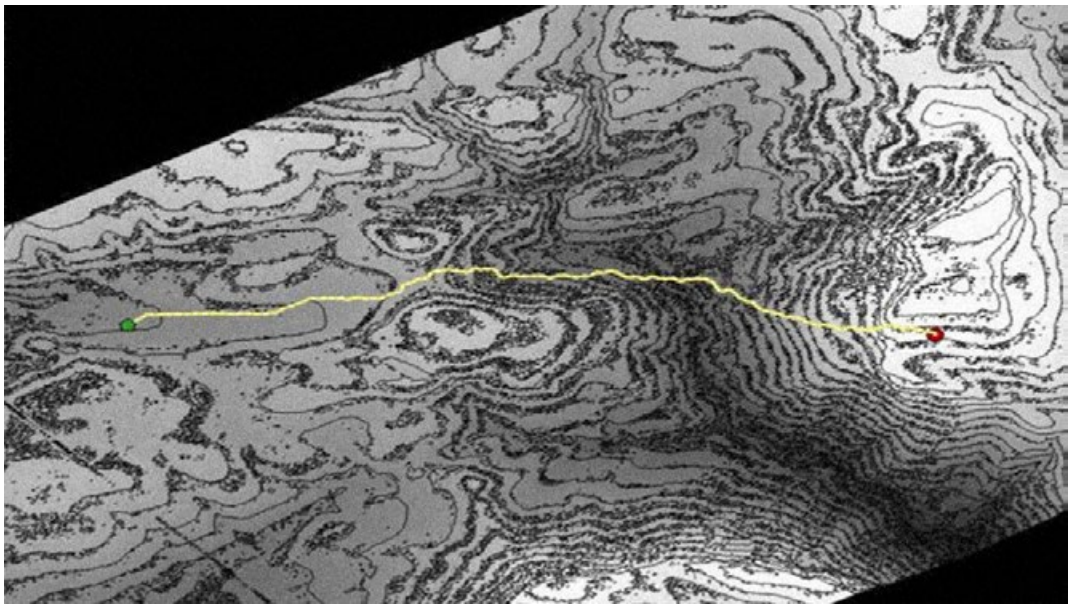
SS_015_2019

ENJAMBRE

Critical emergency missions with manned and unmanned aerial vehicles in cooperative flights.



Lower cost route between the position of the brigade (red dot) and the position of the camp or safe area (green dot).

PROBLEM DESCRIPTION

Development of intelligent systems to provide an advanced route control, allowing cooperative operations between manned aircrafts and RPA (observational operations), helping to characterize the territory and making the unload operations during fights against forest fires more efficient.

CHALLENGES AND GOALS

- ✔ Elaboration of several expert systems for decision making, based on different kinds of information stored in large databases.
- ✔ Algorithms for temperature data treatment and calculation of escape routes for the fire fighting squads will be developed.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Statistical modelling.
- ✔ Mathematical Optimization.
- ✔ Analysis and programming of mathematical algorithms.
- ✔ R and Python programming.
- ✔ Databases (especially postGis).
- ✔ GIS systems (QGIS and PyQGIS, in particular).

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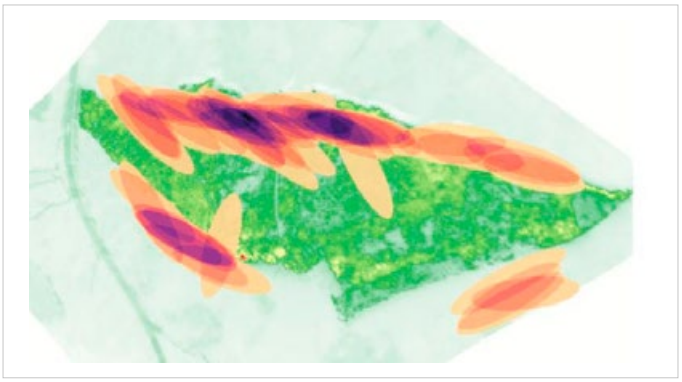
Critical emergency missions with manned and unmanned aerial vehicles in cooperative flights.



Watermark of the discharges made by five aircfraft that participat ed in the extinction of a fire that occurred in Galicia in the summer of 2017.

RESULTS AND BENEFITS

The results of this project will strongly contribute to develop technologies to optimize the efforts dedicated to fire extinction and that allow to reduce the affected surface, as well as increase the security of the brigades, improve the coordination in the extinction operations, extend the time zone of action and introduce new aerial resources in the fight against major forest fires.

Likewise, the investment, operation and maintenance costs of the operations can be reduced, increasing the coverage and efficiency of the service.

Databases to feed intelligent systems have been generated and their performance has been validated.

The company has highly precise information allowing to characterize the territory and feed the expert system linked to information from the National Forest Inventory (IFN3).

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Success story

COMPANY
VICUSdt

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ITMATI (Instituto Tecnológico de Matemática Industrial), USC

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SS_014_2019

GPEC

Green Port Energy Center.

Polygeneration clusterizable containerized system that supplies electrical and thermal energy to the ship

PROBLEM DESCRIPTION

Reduce emissions related with port activities developing a system to supply electrical and thermal energy to a ship at port.

CHALLENGES AND GOALS

The aim of this project is to improve energy efficiency and reduce emissions related with port activities, developing a polygeneration clusterizable containerized system that supplies electrical and thermal energy to the ships, generated from liquefied natural gas engine, to prevent operating with theirs auxiliary groups during their stay in port.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Exploratory Statistical Analysis.
- ✔ Statistical modelling: flexible regression models (Generalized Additive Models, GAM).
- ✔ R programming.

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VICUSdt

RESEARCH CENTRE
ITMATI (Instituto Tecnológico de Matemática Industrial), USC

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SS_014_2019

GPEC

Green Port Energy Center.

Aerial view of Vigo S port (World Port Source)

RESULTS AND BENEFITS

- A profile of energy demand has been obtained without the need to carry out complex and expensive preliminary energy studies.
- Relative to diesel, it has brought a CO2 emissions reduction of 20%.
- Energy has been obtained through clean generation systems installed in the port.
- A computer tool that allows the calculation of cost-benefit of the use of the GPEC system during the stays in port of the ships, in terms of both energy efficiency and emission reduction, has been developed.

Design and development of a polygeneration clusterizable containerized system that supplies electrical and thermal energy to the ships.

EU-MATHS-IN Success story

COMPANY
Reganosa

RESEARCH CENTRE
ITMATI and Universidade de Santiago de Compostela

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SS_013_2019

GANESO

Simulation and optimization of gas networks. Gas transmission network modelling, simulation and optimization.

National Natural Gas Network represented in the graphic interface of the GANESO software.

PROBLEM DESCRIPTION

Research and development on the integrated and optimal management of natural gas transmission infrastructures.

CHALLENGES AND GOALS

- ✔ Development of GANESO software, an IT tool that allow clients to interactively obtain optimal distribution of the gas flow based on different criteria, tariff calculation, simulation in transient conditions, and network expansion planning under uncertainty.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Steady state and transient state simulation.
- ✔ Steady state optimization.
- ✔ Modelling with numerical simulation physical processes.
- ✔ Planning under uncertainty using s tochastic programming.
- ✔ Calculation of network access tariffs.
- ✔ Parallel computing.

In order to optimize the gas transport network, a two stage procedure has been developed:

- ✔ Disregarding some second order physical effects, a first algorithm obtains an initial solution, which is used to configure the network (compressor stations, PCVs, Based on Sequential Linear Programming techniques.
- ✔ A second algorithm refines the previous solution with the aid of a simulator Based on Control Theory techniques.

COMPANY
Reganosa

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SS_013_2019

GANESO

Simulation and optimization of gas networks. Gas transmission network modelling, simulation and optimization.

Configuration of a case study of the Spanish Gas Network.

RESULTS AND BENEFITS

GANESO allows to study the use of current infrastructures, optimize them and assess the investment in future infrastructures, enabling, in this sense, users to make decisions regarding management and expansion of gas transportation networks.

The software helps when making strategic decisions for the company, which reduces costs. In addition, it is competitive with existing commercial tools since it presents a great advantage for the company: control over future developments, tariff calculations and can incorporate new features on demand.

Design and development of an innovative simulation and optimization software (GANESO) based on a new techniques of mathematical programming and applied mathematics.

Decision making tool.

EU-MATHS-IN
Success story

COMPANY
Fundiciones Rey

RESEARCH CENTRE
ITMATI, USC & UVigo

PRODUCTIVE SECTOR
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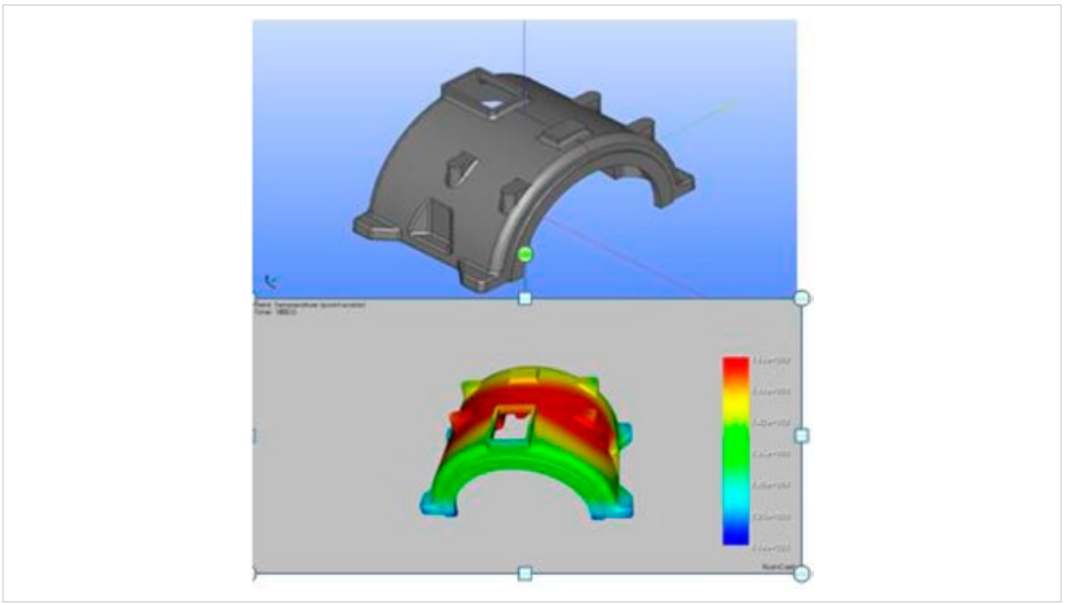
SS_012_2019

FUNDICIONES REY

Metal casting processes and metallurgical treatments.



Mathematical modelling and numerical simulation for the heat transfer on foundry solidification bearings by CastFEM code.

PROBLEM DESCRIPTION

Mathematical modelling and numerical simulation for solving the thermal problem arising in the solidification (phase-change) of a metal casting inside a sand mould.

Subsequently, quenching processes produce microstructure metallurgical transformations that are responsible for modifications in mechanical properties.

CHALLENGES AND GOALS

Replace or complement the tests in casting processes and thermal treatments of bearings to reduce material and energy costs, improving the life of the equipment and the final quality of the products.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Mathematical Modelling: Partial Differential Equations.
- ✔ Heat transfer: Phase change, Shrinkage cavities, Quenching, Metallurgical microstructures.
- ✔ Finite Element Analysis (FEA): CastFEM (own code), Code-Aster (free software).

EU-MATHS-IN Success story

COMPANY
Fundiciones Rey

RESEARCH CENTRE
ITMATI, USC & UVigo

PRODUCTIVE SECTOR
Energy and Environment

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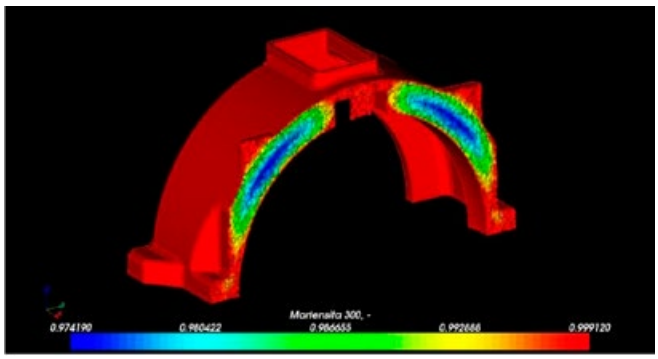
More info

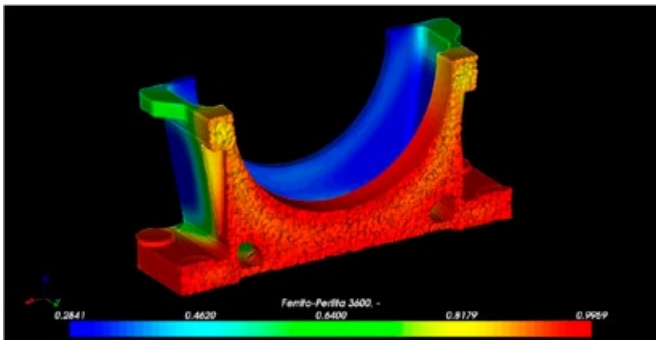
SS_012_2019

FUNDICIONES REY

Metal casting processes and metallurgical treatments.



Numerical simulation of the martensite distribution at the end of quenching (pool boiling) by Code-Aster.



Numerical simulation of the ferrito-perlite distribution at the end of quenching (forced convection) by Code-Aster.

RESULTS AND BENEFITS

The result of the project has been the development of a numerical simulation tools that allow to analyze in detail the process of thermal treatment of metals.

These tools allow identifying the weak points of the process and analyzing possible modifications in order to improve the final product.

At the same time. the developed tools are very flexible and easily modified to be able to predict the thermal treatment of pieces in other conditions (in the face of both a redesign of the operation and the design of a new process).

Using the numerical simulation, the company got great advantages instead of using experimental tests.

“The numerical simulation has great advantages over experimental testing, thereby reducing material cost and energy and, in general, associated with final product quality.”

(Fundiciones Rey)

EU-MATHS-IN Success story

COMPANY
Seguros Lagun Aro

RESEARCH CENTRE
BCAM (Basque Center for Applied Mathematics)

PRODUCTIVE SECTOR
Economy and finance

Digital Twin

SS_011_2019

LAGUN ARO

Machine learning to improve customer satisfaction in insurance.

Offices al Laboral Kutxa where Seguros Lagun Aro operates

PROBLEM DESCRIPTION

Seguros Lagun Aro wanted to increase customer satisfaction and prevent them from leaving the company by optimizing predictive models through Machine Learning techniques.

CHALLENGES AND GOALS

- ✔ To define mathematical models to better understand customer behaviour and to find the most suitable algorithm to create an effective prediction model.
- ✔ To develop a software that will allow the company to identify those customers who are more likely to void their policies.

MATHEMATICAL AND COMPUTATIONAL METHODS

The goal of the project is to use Machine Learning to perform an in-depth analysis of customer data to improve customer satisfaction and identify those customers who are less satisfied with the service.

In that sense, probabilistic methods were used to design specific classifiers for dealing with the prediction of customer churn (clients voiding their policies).

After that, we proceeded to the evaluation of the quality of the models learnt by means of robust estimation methods.

COMPANY
Seguros Lagun Aro

RESEARCH CENTRE
BCAM (Basque Center for Applied Mathematics)

PRODUCTIVE SECTOR
Economy and finance

Digital Twin

SS_011_2019

LAGUN ARO

Machine learning to improve customer satisfaction in insurance.

RESULTS AND BENEFITS

Currently, the mathematical model developed by BCAM is used by the company – in a complementary manner to other methods – to predict customer loss and retention probabilities.

The software allows the company to re-train the models in a streaming fashion; this is done in a reasonable period of time, considering the great volume of data with which they work.

The company counts with an effective prediction model to identify customer loss and retention probabilities.

EU MATHS IN

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bcam basque center for applied mathematics

LAGUN ARO

Data Science Group at BCAM.

COMPANY
Lantek

RESEARCH CENTRE
Basque center for applied mathematics

PRODUCTIVE SECTOR
Materials

SS_010_2019

LANTEK

Computational speed-up of 2D packing. Efficient implementation of 2D nesting problem to minimize waste of metal.

2D nesting problem: the rectangular container is to be filed by 2D objects to minimize the waste (grey).

PROBLEM DESCRIPTION

Lantek's goal was to find the optimal layout of 2D pieces on a large metal rectangular sheet to minimize the waste material in the sheet cutting through an efficient implementation of 2D nesting problem.

CHALLENGES AND GOALS

To design an efficient algorithm for the 2D nesting (packing) problem and to improve the current by boundary representations in order to develop a software that will speed up computations.

COMPANY
Lantek

RESEARCH CENTRE
Basque center for applied mathematics

PRODUCTIVE SECTOR
Materials

SS_010_2019

LANTEK

Computational speed-up of 2D packing. Efficient implementation of 2D nesting problem to minimize waste of metal.

Lantek employee working on the Packing software.

Lantek headquarters located in the Araba Science and Technology Park.

MATHEMATICAL AND COMPUTATIONAL METHODS

A discrete curvature measure was used to find the best match between two objects. The algorithm is based on D-function and non-fitting polygon approach.

RESULTS AND BENEFITS

The boundary representation of the objects (so far polygons, later NURBS curves) is more efficient for the overlapping test than the pixel-to-pixel comparison of two areas. This allows for a computational speed-up of 2D packing, that will ultimately result in the reduction of the waste of material.

The computational speed-up of 2D packing will ultimately result in the reduction of the waste of material.

EU-MATHS-IN
Success story

COMPANY
REPSOL

RESEARCH CENTRE
ITMATI and Universidade de Santiago de Compostela

PRODUCTIVE SECTOR
Energy and Environment

Digital Twin

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SS_009_2019

REPSOL-ITMATI JRU

REPSOL-ITMATI Joint Research Unit.

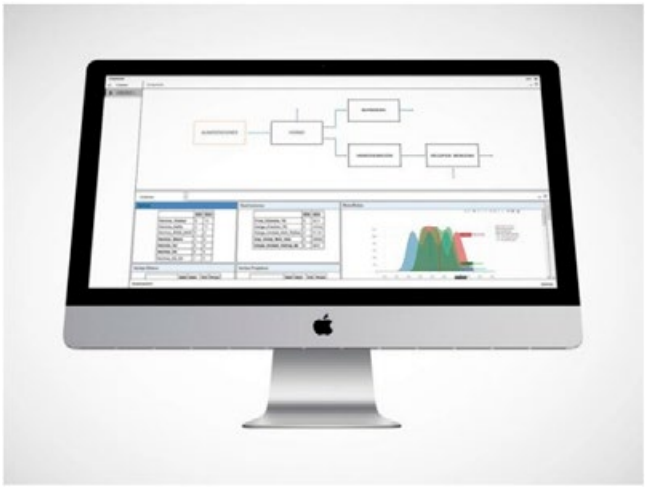

Image captured from the interface of an optimization tool under uncertainty of industrial process plants, research line 1 of the Repsol-ITMATI Joint Research Unit.

PROBLEM DESCRIPTION

A Joint Research Unit has been created in order to carry out research on mathematical and numerical methods to solve problems on a recurring basis in the daily activity at Repsol, especially in the fields of simulation and optimization of devices and processes.

CHALLENGES AND GOALS

- ✔ To increase the working life of batteries used in electric vehicles.
- ✔ To improve the fast recharging process of the battery.
- ✔ In the production planning in industrial facilities: to integrate into the decision-making processes the uncertainties relating to prices, demands, and the quality of raw materials and products.

MATHEMATICAL AND COMPUTATIONAL METHODS

- ✔ Modelling of physical and chemical processes.
- ✔ Numerical methods for solving ordinary and partial differential equations.
- ✔ Mathematical optimization.
- ✔ Stochastic optimization.
- ✔ Control Theory.
- ✔ Order reduction techniques.
- ✔ Parallel programming and Supercomputing.
- ✔ Use of field-programmable gate arrays (FPGAs).
- ✔ Use of field-programmable analog arrays (FPAAs).
- ✔ Quantum computing.

COMPANY
REPSOL

RESEARCH CENTRE
ITMATI and Universidade de Santiago de Compostela

PRODUCTIVE SECTOR
Energy and Environment

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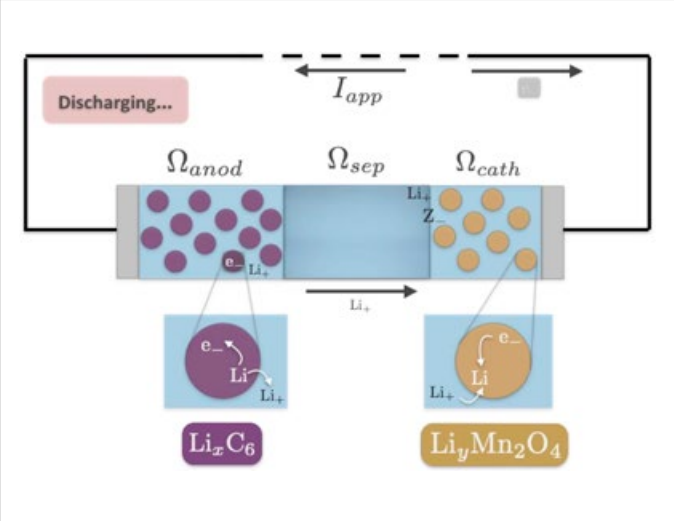
REPSOL-ITMATI JRU

REPSOL-ITMATI Joint Research Unit.



Schematic of a Lithium ion cell.

Corporate Image of the Joint Research Unit (JRU).

RESULTS AND BENEFITS

The competitive advantages obtained by Repsol within the framework of this collaboration are the optimization of their industrial processes, an improvement in the company ‘s efficiency and product design and the development of decision-making tools.

This research will enable the company to reduce production costs as well as to shorten development times of new technologiesand bring about more noteworthy innovations as compared with theirs competitors.

Solving planning production problems in industrial processing plants: improved decision-making via mathematical optimization.

Development of a rigorous physics-based simulator of batteries for electric cars.

COMPANY
EcoMT Ecomanagement Technology

RESEARCH CENTRE
ITMATI. Spanish Network for Mathematics & Industry (math-in)

PRODUCTIVE SECTOR
Energy and Environment

Digital Twin

More info

SS_008_2019

ECOMT

Predictive maintenance in air conditioning systems.

OTEA controls, monitors and manages energy like a "business intelligence".

PROBLEM DESCRIPTION

Implement improvements in the OTEA platform, developing an algorithm which predicts incidence risk in the air-conditioning system, taking the machine's operating mode into account (cooling or heating).

CHALLENGES AND GOALS

Representation of the forecast of incidents on a map to create a heat map for air conditioning systems.

MATHEMATICAL AND COMPUTATIONAL METHODS

Proposed model.

Use of the generalized additive models, GAM, to predict response variables from observations:

- ✔ As covariables, for modelling the cooling regime, the maximum daily ambient temperature of the previous day, the average daily climate consumption before opening and the member of the last days with incidents are included.
- ✔ The model for the heating regime includes the number of the last five days with incidents, the average daily temperature and the daily average climate consumption before the opening.

COMPANY

EcoMT Ecomanagement Technology

RESEARCH CENTRE

ITMATI. Spanish Network for Mathematics & Industry (math-in)

PRODUCTIVE SECTOR

Energy and Environment

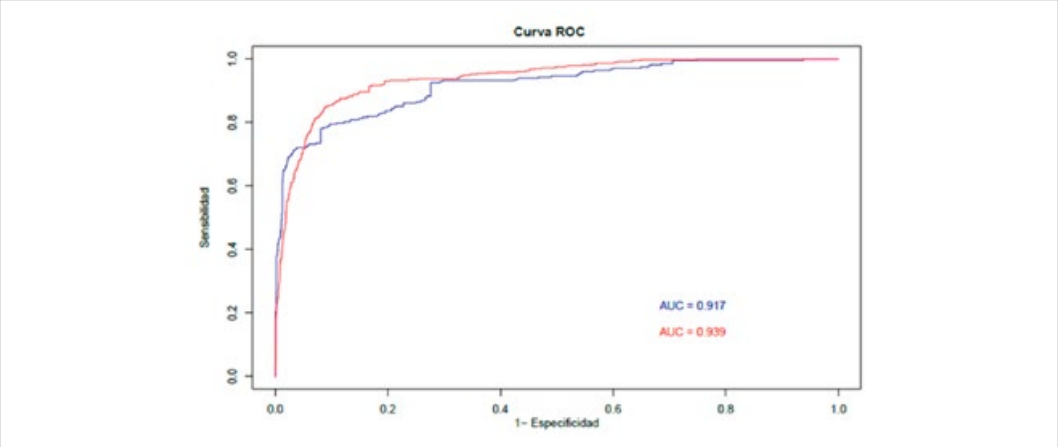
Digital Twin

More info

SS_008_2019

ECOMT

Predictive maintenance in air conditioning systems.



ROC curves for the cooling model (blue line) and for the heating model (Red line).

RESULTS AND BENEFITS

The knowledge foundation that has been created is exploited to represent on the map the geographical distribution of the incidents according to size.

It shows, with a high degree of reliability, which commercial premises could pose problems throughout the day. Through the forecasting of potential incidents, which can be obtained before opening hours, and taking into account the number of machines each shop is equipped with, a list of the stores that are most at serious risk are provided.

Reduction in corrective maintenance costs, which are directly related to failure forecasting in air-conditioning systems.

EU-MATHS-IN
Success story

COMPANY
SARI S.A. (NORS Group)

RESEARCH CENTRE
Laboratório de Engenharia Matemática do Instituto Superior de Engenharia do Porto

PRODUCTIVE SECTOR
Service Management

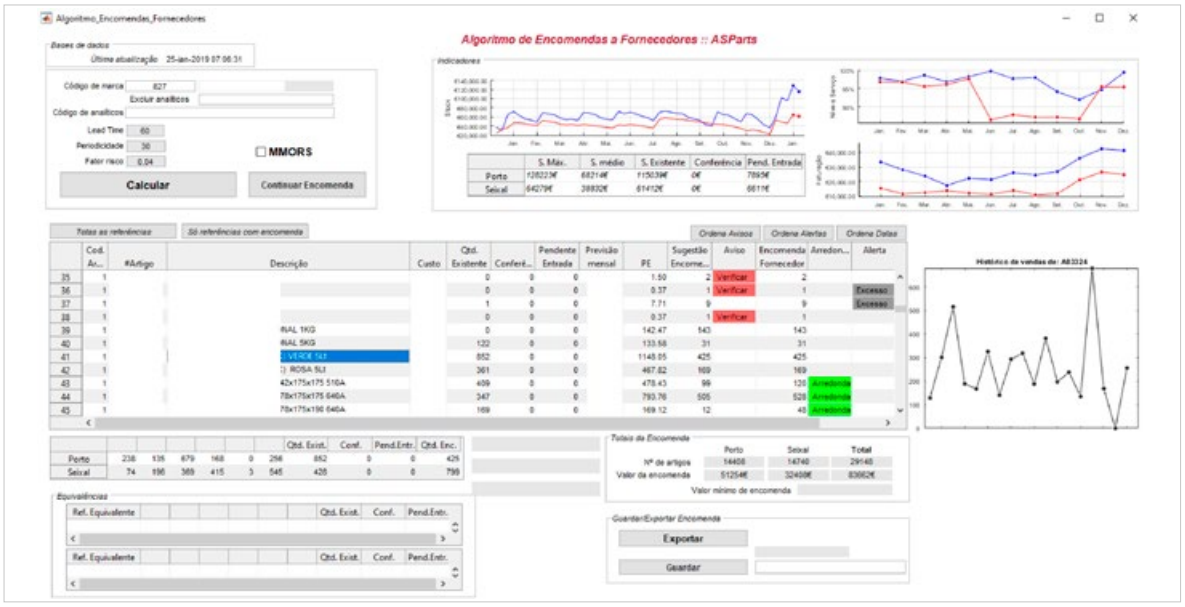
Digital Twin

More info

SS_007_2019

NORS

Optimizing an automotive wholesaler stock management Modelling, Simulating and Optimizing the stock of a spare parts wholesaler.



MMORS front-end

PROBLEM DESCRIPTION

Nors is one of the largest Portuguese groups in the automotive sector, acting worldwide. With around 8 M€ in stock, around 200 K parts numbers, and more than 120 suppliers with different logistic setups, a company from the Nors group needed a efficient way to manage its order system, regarding its spare part business.

CHALLENGES AND GOALS

- ✔ To guarantee an excellent service level.
- ✔ To reduce logistic costs.
- ✔ To optimize the return of available budget.
- ✔ To implement the model as an external layer to the existing ERP.

MATHEMATICAL AND COMPUTATIONAL METHODS

In 2013 the Engineering Mathematical Lab (LEMA) from Oporto School of Engineering (ISEP IPP) was challenged to develop a tailor made mathematical tool to control the stock management in the companies of NORS group that operate on the aftermarket sector. To do so, firstly were defined which were the best metrics to meet the managers goals. Afterwards, data analysis techniques were applied to detect which type of patterns were present on sales. With this information, an automatic forecasting model with several prediction methods was built. Simulating different scenarios, the forecasting model was then tuned. Finally, to take advantage of the group sales volume, an optimization model (MMORS) was implemented in order to minimize logistical costs.

COMPANY
SARI S.A. (NORS Group)

RESEARCH CENTRE
Laboratório de Engenharia Matemática do Instituto Superior de Engenharia do Porto

PRODUCTIVE SECTOR
Service Management

Digital Twin

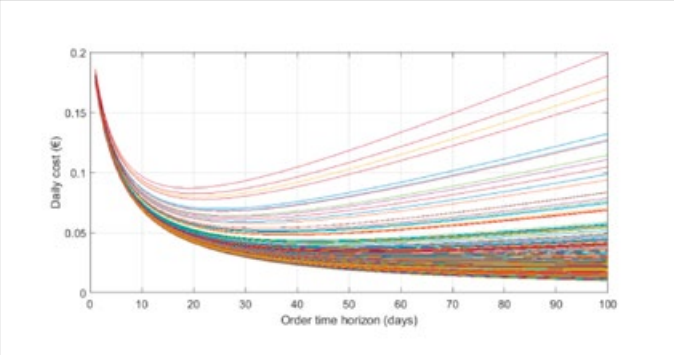
More info

SS_007_2019

NORS

Optimizing an automotive wholesaler stock management Modelling, Simulating and Optimizing the stock of a spare parts wholesaler.

MMors (blue) vs Original (red) cumulative lost sales value for a given family of spare parts.



Daily cost vs order time horizon for a set of spare parts.

RESULTS AND BENEFITS

One year after MMORS fully implementation, the Mean Daily Stock was reduced around 18%, while the Service level was increased around 1%. All of those in a year where the gross sales were increased by 9%. All the model was implemented in a tailor made software that, although being nowadays the core of the company ordering system, didn't imply any major changes on their existing ERP.

One year after the full implementation, the company.

Mean Daily Stock was reduced around 18%.

COMPANY
SMARTGEO

RESEARCH CENTRE
CMUC

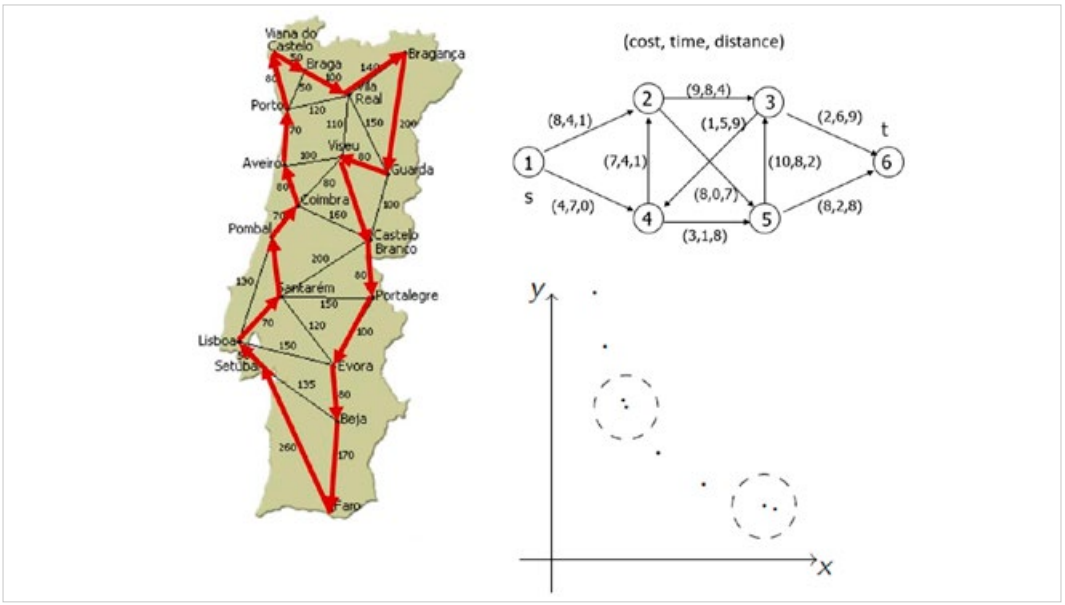
PRODUCTIVE SECTOR
Logistics and Transport

Digital Twin

SS_006_2019

SMARTGEO

Multiple-criteria optimization for mobile agents in a network.



A Hamiltonian cycle (left).

A network example with 3 criteria (right upper corner).

New dominance criteria (right bottom corner).

PROBLEM DESCRIPTION

The company Smartgeo Solutions was interested in developing an application, which operates on a Web platform, to optimize routes of mobile agents considering multiple criteria in the decision process.

CHALLENGES AND GOALS

- ✔ Compute efficient routes of mobile agents.
- ✔ Considering multiple criteria in the decision process.
- ✔ Control the number of efficient solutions determined and the time spent to get them.

MATHEMATICAL AND COMPUTATIONAL METHODS

The problem was modeled using a multicriteria version of the multiple traveling salesman problem with multiple depots. Labeling algorithm and new heuristics were proposed to find solutions of this problem. Additionally, a new dominance criterion was introduced to speed up the methods used.

COMPANY
SMARTGEO

RESEARCH CENTRE
CMUC

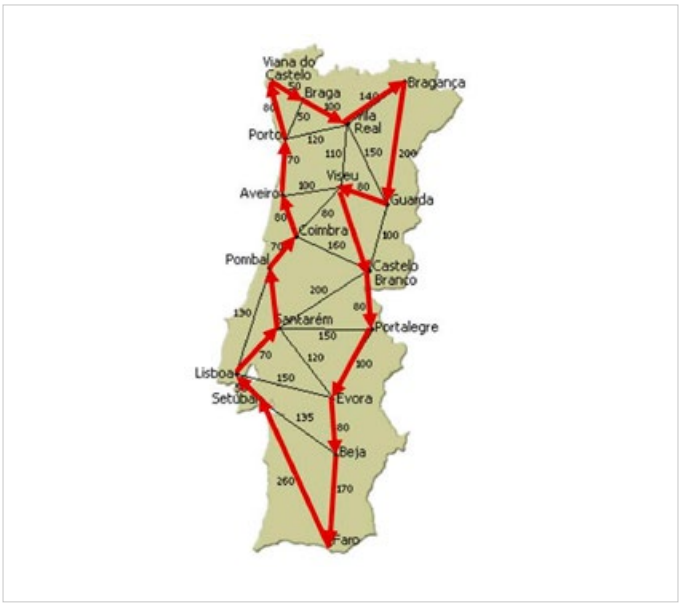
PRODUCTIVE SECTOR
Logistics and Transport

Digital Twin

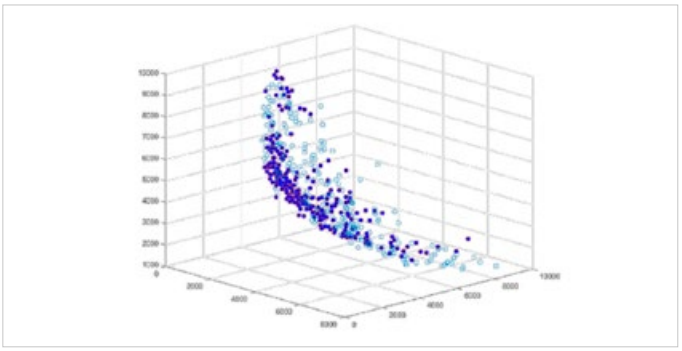
SS_006_2019

SMARTGEO

Multiple-criteria optimization for mobile agents in a network.



Routes for each one of the mobile elements.



Pareto optimal solutions on 3 criteria network with 15 nodes

RESULTS AND BENEFITS

The straight result is the development of new algorithms to obtain solutions for the multiple traveling salesman problem with multiple depots. These algorithms constitute the basis of the prototype to optimize the route of the mobile agents in the network and allow to explore solutions that had not been found with classic approaches. Since several criteria are considered simultaneously, the decision maker is able to choose the best solution in each scenario.

The company has a prototype to include on its platform to optimize the routes of mobile agents in a network considering several criteria simultaneously.

EU MATHS IN
OpenDesk BY EU-MATHS-IN
CMUC Centro de Matemática Universidade de Coimbra
Universidade de Coimbra
smartgeo

EU-MATHS-IN Success story

COMPANY
Monte Carlo Yatchs

RESEARCH CENTRE
SISSA mathLab group

PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

SS_005_2019

SOPHYA

Seakeeping of planing hull yachts. An experimentally validated computational pipeline for the seakeeping design of planing hulls.

A rendering of the CFD simulation results superimposed to the actual wave pattern past a yacht advancing in non calm sea conditions.

PROBLEM DESCRIPTION

MCY is among the leading Italian producer leisure yachts. The main goal is to improve the seakindness and comfort of the planing hulls in non calm sea conditions.

CHALLENGES AND GOALS

- ✔ Develop and validate new simulation tools for planing yachts also accounting for non calm sea conditions.
- ✔ Obtain a parametric formulation of the original shape.
- ✔ Develop model order reduction techniques for fast and reliable optimization campaigns.

MATHEMATICAL AND COMPUTATIONAL METHODS

Many components of the optimization algorithm of a planing hull yachts have been developed in the project:

- ✔ The hull geometry is deformed with a specifically developed shape parameterization strategy in which the mesh for the CFD simulations is modified along with the CAD geometry of the hull.
- ✔ The full order model based on finite volume approach allows to simulate the turbulent flow and consider the rigid hull motions in non calm conditions. High-fidelity solution are collected into a database.
- ✔ Proper orthogonal decomposition with interpolation is applied to efficiently compute the solution of a parametric partial differential equations system, exploiting the precomputed solutions database.

COMPANY
MonteCarlo Yatchs

RESEARCH CENTRE
SISSA mathLab group

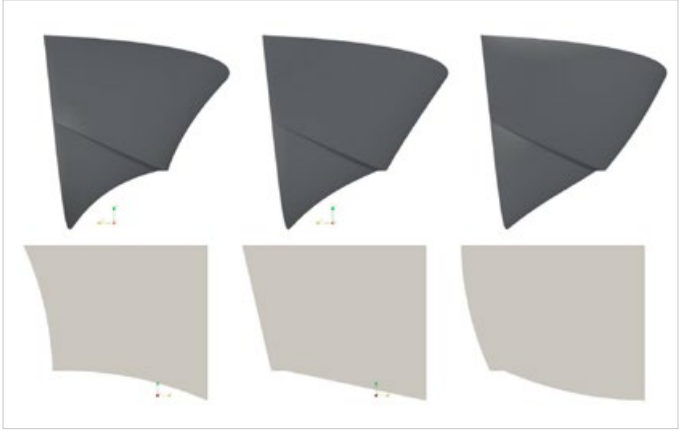
PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

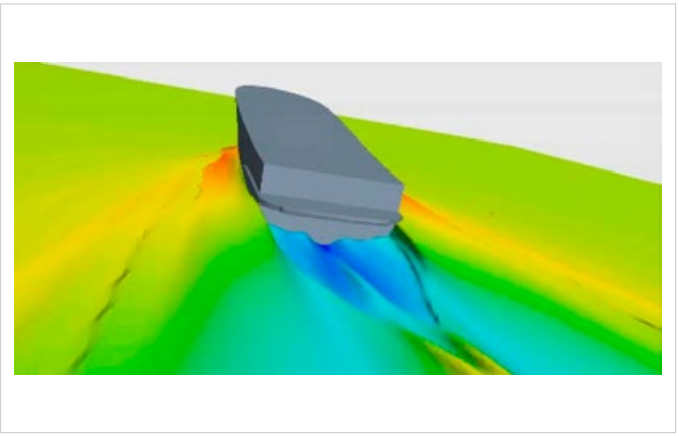
SS_005_2019

SOPHYA

Seakeeping of planing hull yachts. An experimentally validated computational pipeline for the seakeeping design of planing hulls.



Front (top) and rear (bottom) view of hull deformations obtained modifying the surface curvature.



Visualization of the wake generated by the flow past a yacht.

RESULTS AND BENEFITS

The experimental effort of the project results in validated simulation tools. The full optimization pipeline composed by shape parameterization, full order simulation and model reduction tools has been put to test to generate a new, optimized hull. After further validation through towing tank tests, the optimized hull will be put in production by MCY.

The company now has a new efficient design pipeline to develop hulls with increased comfort. A first optimized hull will be soon entering the market.

SISSA mathLab group.
Innovating with mathematics.

EU-MATHS-IN
Success story

COMPANY
CETENA S.p.A

RESEARCH CENTRE
SISSA mathLab group

PRODUCTIVE SECTOR
Mechanics and Mechatronics

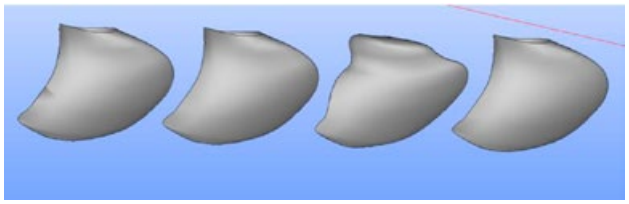
Digital Twin

SS_004_2019

PRELICA

Reduction of noise generated by propellers.
Shape optimization of naval propellers in order to reduce the hydro acoustic noise.

PPTC benchmark propeller.



deformation of a PPTC benchmark propeller blade.

PROBLEM DESCRIPTION

CETENA S.p.A., a Fincantieri company, was interested in reducing the hydro acoustic noise generated by propeller blades within the project PRELICA “Advanced methodologies for hydroacoustic design of naval propulsion”, supported by Regione FVG, POR-FESR 2014-2020, Piano Operative Regionale Fonda Europeo per lo Sviluppo Regionale.

CHALLENGES AND GOALS

- ✔ Efficient prediction of noise given a propeller geometry.
- ✔ Reliable shape parametrization and morphing tool.
- ✔ Reduction of noise of an actual propeller.

MATHEMATICAL AND COMPUTATIONAL METHODS

We had to implement a bottom-up approach to parametrize and then morph a single propeller blade given the radial distribution of chord, pitch, rake, and skew. Modifying the displacement of some control points defining the aforementioned radial distribution functions we are able to generate a wide range of different propeller designs in both CAD files as iges and stl, and PROCAL files as ppg. Due to the high number of possible geometrical parameters we exploited the active subspaces property of the target functions describing the hydro acoustic performance and numerical simulations based on potential theory in order to reduce the parameter space dimensionality and assess the most relevant parameters. This resulted in only few promising geometrical configurations. Finally more accurate numerical simulations based on RANS and LES were performed by the company to assess the effectiveness of the selected propeller and find the best candidate.

COMPANY
CETENA S.p.A

RESEARCH CENTRE
SISSA mathLab group

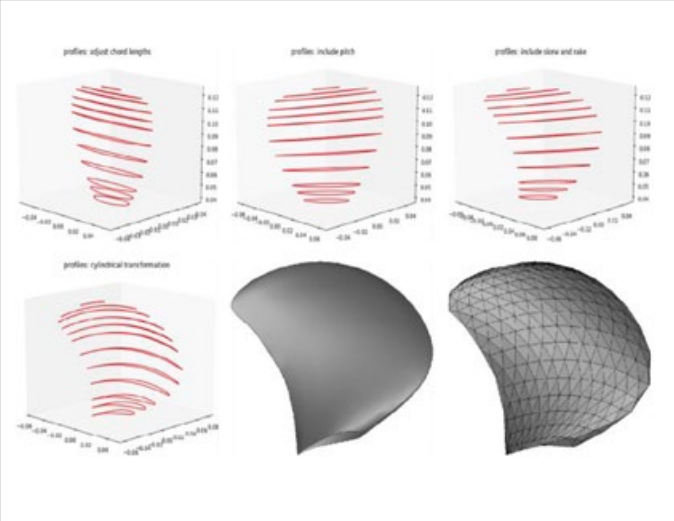
PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

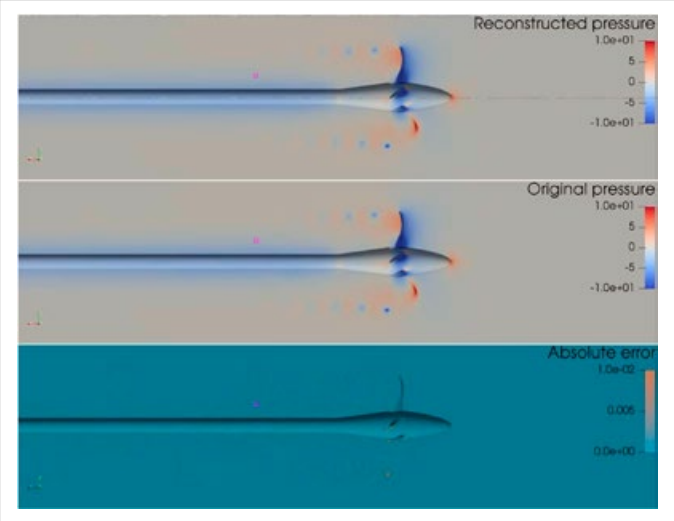
SS_004_2019

PRELICA

Reduction of noise generated by propellers. Shape optimization of naval propellers in order to reduce the hydro acoustic noise.



Construction of a propeller blade and CAD representation.



Representation of the approximated pressure fields, of the original one and of the absolute error.

RESULTS AND BENEFITS

The results of this collaboration are: the creation of BladeX, a open source Python package, to generate, morph, and export different propeller geometries, with a dedicated web app for the company to use; the identification of the most important parameters affecting the hydro acoustic noise; the identification of the most promising design shapes. The collaboration resulted also in several scientific works in preparation and some already submitted.

The company has a computational methodology to parametrize and morph propeller geometries, resulting in different geometrical configurations. So it is able to design and optimize the acoustic behavior of their naval propellers

SISSA mathLab group.
Innovating with mathematics.

EU-MATHS-IN Success story

COMPANY
Ficantiery

RESEARCH CENTRE
SISSA mathLab group

PRODUCTIVE SECTOR
Mechanics and Mechatronics

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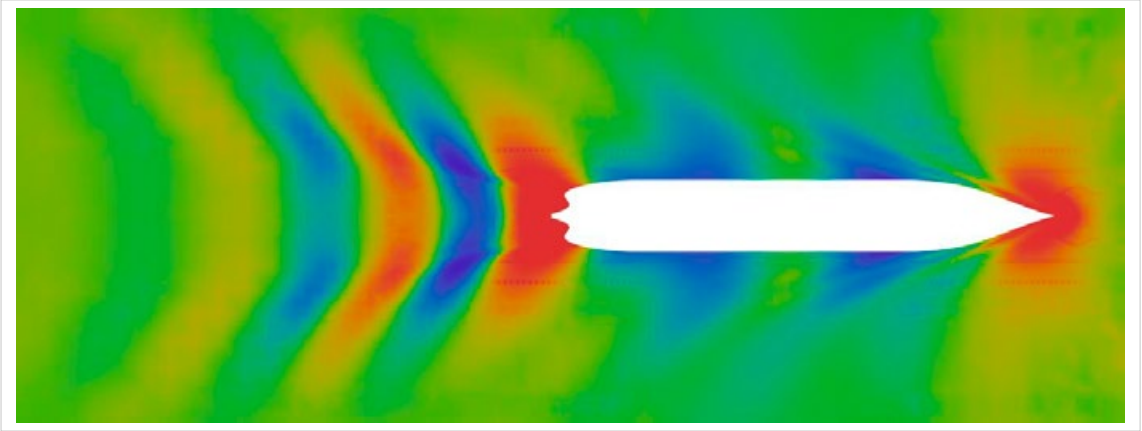
SS_003_2019

DATA DRIVEN SHAPE OPTIMIZATION SYSTEM

An efficient computational pipeline to reduce the ship resistance in calm water scenario.



Computational fluid dynamics simulation of a cruise ship advancing in calm water.

PROBLEM DESCRIPTION

Fincantieri S.p.A., one of the largest shipbuilding companies in the world, was interested in an efficient shape optimization framework to reduce the hydrodinamic ship resistance. The aim is to achieve a remarkable reduction of the fuel consumption in the new cruise ships.

CHALLENGES AND GOALS

- ✔ Obtain a parametric formulation of the original shape.
- ✔ Increase the efficiency through the exploitation of model order reduction techniques.
- ✔ Integrate all the tools to provide a black-box framework to optimize a certain objective function.

MATHEMATICAL AND COMPUTATIONAL METHODS

The resulting optimization framework consists in a numerical pipeline composed by several tools.

- ✔ Free-form deformation is applied to hull shape to deform the original ship.
- ✔ The finite volume approach allows to simulate the turbulent flow. We collect the high-fidelity solutions database for some properly chosen configurations.
- ✔ We use dynamic mode decomposition to accelerate a single numerical simulation, thanks to its capability to individuate the system dynamics.
- ✔ Proper orthogonal decomposition with interpolation is applied to efficiently compute the solution of a parametric partial differential equations, exploiting the solutions database pre-computed.

Finally, we adopt a global optimization algorithm over the reduced space in order to converge to the optimal shape.

COMPANY
Ficantiery

RESEARCH CENTRE
SISSA mathLab group

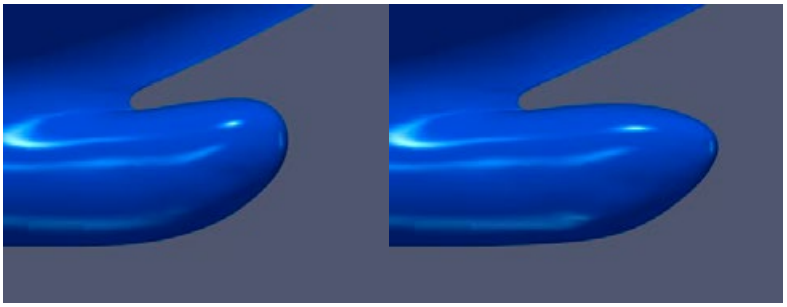
PRODUCTIVE SECTOR
Mechanics and Mechatronics

Digital Twin

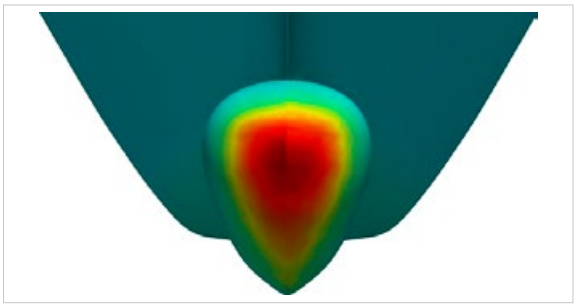
SS_003_2019

DATA DRIVEN SHAPE OPTIMIZATION SYSTEM

An efficient computational pipeline to reduce the ship resistance in calm water scenario.



Example of pipeline application: the original bulb (left) and the optimized one (right).



Visualisation of the total drag: on the right the output from reduced order model, on the left the output from full-order model.

RESULTS AND BENEFITS

During the collaboration, three open source packages containing the adopted methodologies, PyDMD, EZyRB and PyGeM, have been developed and they have been integrated to build the pipeline. The resulted optimization system has been tested to optimize the bulbous bow and the stern of (existing and prototype) cruise ships: the total drag of the ship has been reduced and the over-all execution time, respect to conventional ptimization frameworks, has drastically shortned.

The company has an efficient and integrated data-driven framework to design, optimize and validate the hull shape.

Moreover the modularity of the pipeline allows to replace the components or extend them.

SISSA mathLab group
Innovating with mathematics.

Fincantieri S.p.A.
Italian company leader in cruise ship manufacturing.

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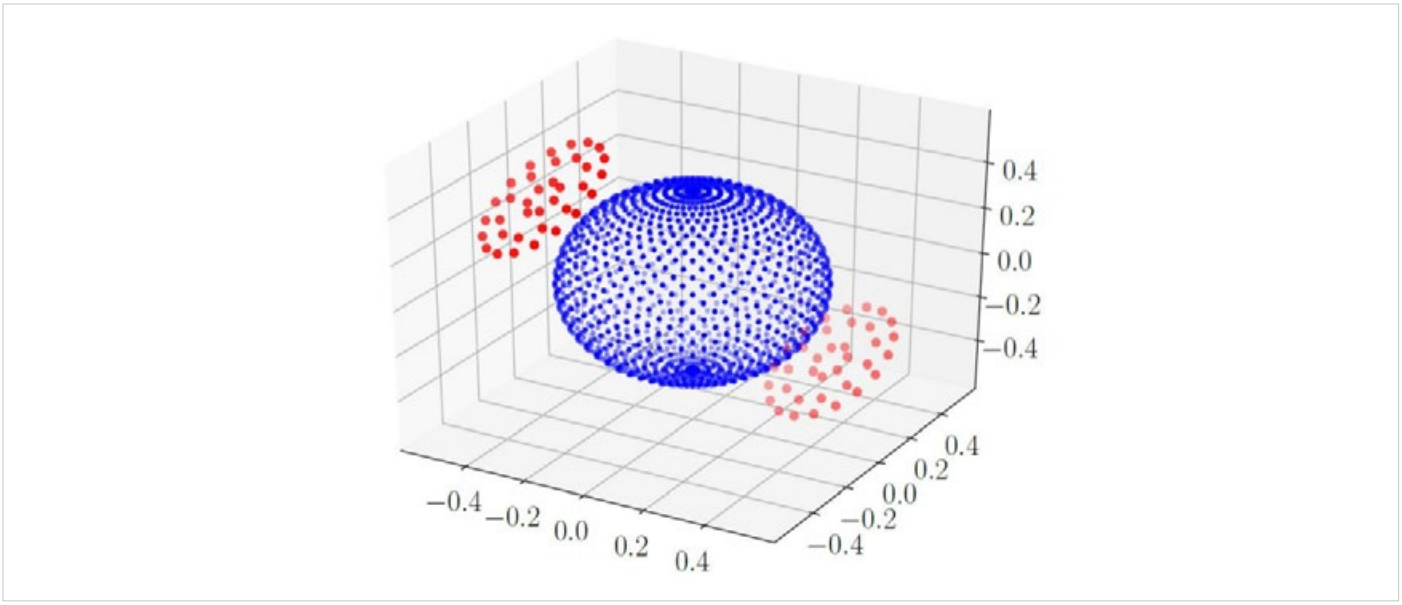
MICRODB

Advanced statistics for acoustic imaging. Acoustic source reconstruction with noisy data.



PROBLEM DESCRIPTION

Acoustic imaging problems consist in identifying acoustic sources from microphone array noisy measurements and quantifying their sensitivity to external, uncontrolled perturbations. Important issues on spatial positions of the microphone arrays arise in sequential acquisitions.

CHALLENGES AND GOALS

To measure the sensitivity of reconstruction methods to external nuisance parameter (reflection property, temperature, etc.) and to construct an experimental design in a sequential learning context.

MATHEMATICAL AND COMPUTATIONAL METHODS

A mathematical model provides us with a framework for sources reconstruction from given measurements. This ill-posed linear inverse problem can be solved among others by classical beamforming approaches or Bayesian algorithms. Advanced statistical tools are involved in the analysis of the sensitivity to external conditions. To better identify the positions of the microphones, a sequential measurement design has been constructed to take advantage of properties of a recent Bayesian algorithm.

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RESULTS AND BENEFITS

Our analysis on sensitivity points out external conditions which strongly influence the stability of the result. A data driven guide for the measurements is given by a new sequential Bayesian experimental design to be implemented on the softwares developed by MicrodB.

Collaboration has been conducted under the FUI program LUG2 (fund ed by BPIFrance and Auvergne-Rhone-Alpes Region).

Industrial software for acoustic source reconstruction using state-of-art statistical methods.

New Bayesian methods for solving ill-posed inverse problems lead to identify the factors that influence the stability of the reconstruction algorithm.

Institut Camille Jordan, Lyon, France.

MicrodB, VibraTec Group, France.

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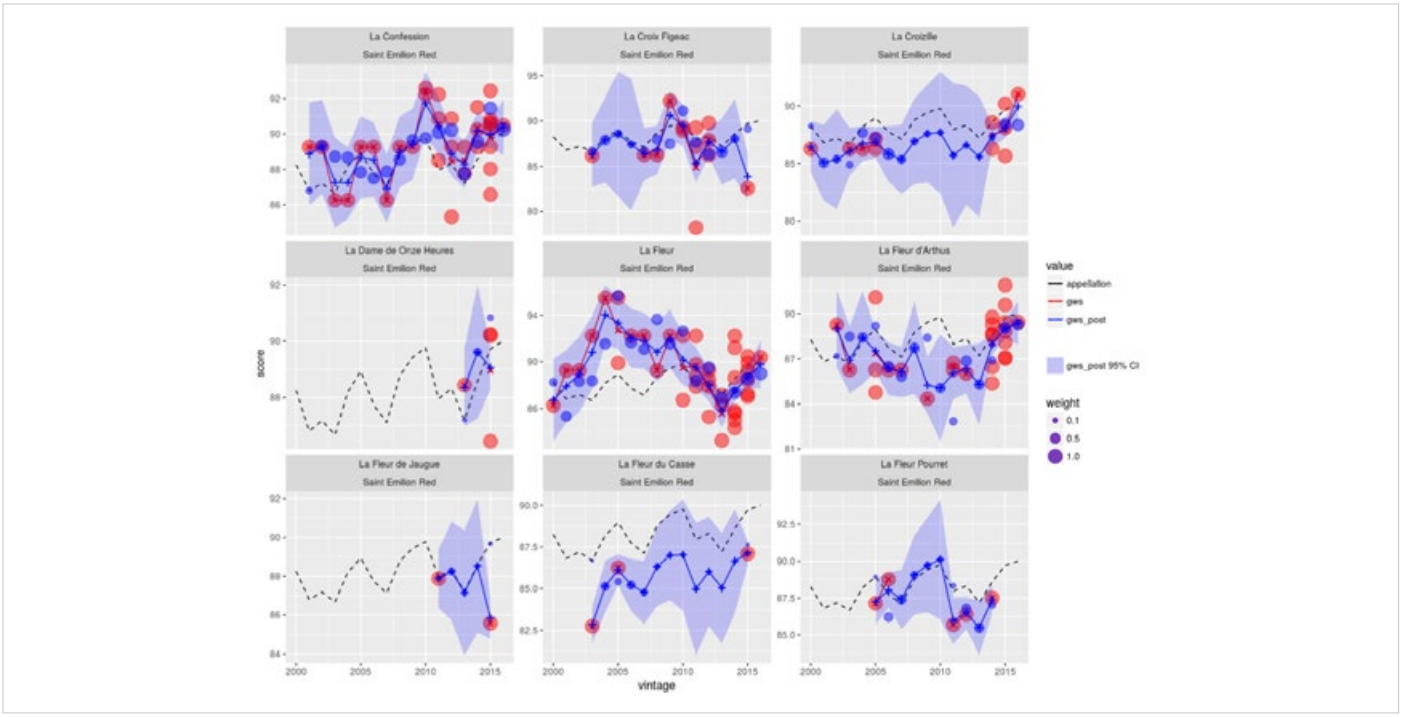
SCORELAB

Global Wine Score. One single score, aggregated from critics.



PROBLEM DESCRIPTION

The Global Wine Score aims at making a single rating system for all wines in the world, from a dataset of more than 1M ratings for more than 100K wines from the 20 most influent wine critics.

CHALLENGES AND GOALS

A lot of wines have been rated very few times. To solve this problem, Scorelab aims at enriching the score with a predictive model based on past evaluations of the wine on prior vintages as well as similar wines, e.g. from the same appellation.

MATHEMATICAL AND COMPUTATIONAL METHODS

Scorelab develops an innovative aggregation algorithm aiming at building the most objective score. A bayesian hierarchical model allowed to estimate the mean and variance of the score of a vintaged appellation. The hierarchical formulation borrow information from similar appellations thus regularizing the estimation for appellations with very few ratings. The inference is based on Monte Carlo Markov Chain methods. The residual scores of each wine over years are modeled with a multisensor Kalman filter whose transition and measurement parameters are also learned from the data.

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SCORELAB

Global Wine Score. One single score, aggregated from critics.

RESULTS AND BENEFITS

Our model allows to obtain a prior distribution for the score of a vintaged wine and its uncertainty, before it receives a single critics rating. The final bayesian score is a weighted average of the observed critics ratings and the prior mean score whose weight is relative to its confidence degree.

A prototype model, allowing to score wines with few critics ratings, with a confidence index.

Assess the quality of all wines in the world with a cutting edge score aggregator.

Use advanced probabilistic learning to improve confidence.

www.eu-maths-in.eu