MATHEMATICAL TECHNOLOGY: INNOVATIVE SOLUTIONS FOR THE INDUSTRY
Background:

2006 - 2011

- Ingenio Mathematica i-MATH Project: Consulting Platform
- CESGA Node
- Consulting & Computing Galicia Network


- [math-in].net (founded in 2011)
- ITM2TI (Instituto Tecnológico de Matemática Industrial) (founded in 2013)
Working Experience with industry since the early 1980s.

- **49%** contracts with industry (2000-2011) are from Galician groups of the Consulting Platform integrated in the CESGA Node.
- More than a hundred transfer initiatives, **70%** led by Galician researchers integrated in CESGA Node (2006-2012).
- More than **200** contracts, collaboration agreements and training courses with companies and institutions in several sectors (1998-2011).
Consolidation capabilities more than 150 scientific researchers of Galician Groups in: Applied Mathematics, Statistical and Operational Research

- **mat+i Group** (Alfredo Bermúdez, Peregrina Quintela, USC)
- **modestya Group** (Wenceslao González, USC)
- **GRID [ECMB] Group** (Carmen Cadarso, USC)
- **MOSISOLID Group** (Juan Manuel Viaño, USC)
- **GSC Group** (Lino José Álvarez, UVigo/USC)
- **MA1 Group** (José Durany Castrillo, UVigo)
- **INFERES Group** (Jacobo de Uña, UVigo)

**CONSORTIUM PROMOTERS/ COLLABORATIVE GROUPS**

- **MODES Group** (Ricardo Cao, Ignacio García, UDC)
- **M2NICA Group** (Carlos Vázquez, UDC)

**Origin of the initiative:** principal Investigators of the CESGA Node, i-MATH project
Centre of technological research in the field of Industrial Mathematics

Public Consortium ITMATI: founding institutions.
- University of A Coruña (UDC)
- University of Santiago de Compostela (USC)
- University of Vigo (UVigo)

Main mission: to increase the competitiveness of industrial enterprises across mathematical technology transfer. Generate innovation creating added value for companies.

- Collaboration agreement for the Creation & Bylaw of ITMATI (18 February, 2013).
- Cooperation agreement which establishes the framework for collaboration between 3 Galician universities & ITMATI (24 March, 2014).
ITMATI operates as a center for technology transfer to the industry

- To facilitate and promote the application of mathematical techniques and methods in the productive sector
- To develop new technological knowledge to improve the competitiveness of the companies in the field of technology and innovation
- To provide services of support to business innovation
- To train technical staff and expert scientists in the areas of Applied Mathematics, Statistical and Operations Research
- To spread the technological knowledge of the Institute
- To boost academic and scientific collaborations with universities and centres of research and transfer and enhance interdisciplinarity
- To help strengthen the relationship between source of knowledge and business
Mathematical Technology

COMPANIES IVERSITIES

“MEETING POINT”

valorization of knowledge

Technological Center
- **40 Affiliated Researchers** of the 3 Galician Universities
- **7 Collaborator Researchers**
- **23 Own staff:**
  - 19 Researchers
  - 1 Manager
  - 1 Technician of Transfer & Innovation
  - 1 IT Technician
  - 1 Administrative Assistant

Most of the researchers at the three Galician universities have a PhD
They worked directly with us

COMPANIES AND ORGANIZATIONS

- AFI (Analistas Financieros Internacionales)
- ALCOA Lista Norway
- Robert Bosch GmbH
- Centro Superior de Estudios de la Defensa Nacional (CESEDEN)
- CIE Galfor S.A.
- Coremain S.L.U.
- ECOMT
- Elkem AS Technology (Noruega)
- Endesa Generación S.A.
- Eramet Norway AS Avd Kvinesdal
- Estaños y Soldaduras Senra S.L.
- Ferroatlántica S.A.
- Fundación Pública Gallega Centro de Supercomputación de Galicia (Fundación CESGA)
- Fundiciones Rey S.L.
- INOVA, Consultores en Excelencia e Innovación Estratégica S.L.
- Instituto Español de Estudios Estratégicos
- Magallanes Renovables S.L.
- Norges Teknisk-Naturvitenskapelige Universitet NTN
- Oxford Center for Industrial and Applied Mathematics (OCIAM)
- Reganosa (Regasificadora del Noroeste S.A).
- Repsol CTR
- Resitec AS
- Saint Gobain Ceramic Material AS
- Sider naval, Equipos Siderúrgicos S.A.
- Silicio Ferrosolar S.L.
- Teknova AS
- Universidade de A Coruña
- Universidade de Santiago de Compostela
- University of Agder (UiA)
- VICUS Desarrollos Tecnológicos
INDICATORS

- Turnover in 2014: **551,529,35€**
- Income from R & D activities represent **95%** of the total turnover in 2014.
- 31 R&D contracts signed since the constitution of ITMATI.
- 25+ Companies & Institutions directly involved.
- 35+ participating institutions.

ECONOMIC DATA

**ITMATI Income in 2014**

- **551,529,35€**
- **95%** Transfer (R&D) contracts.

**Sources of finance**

- R&D Contracts (87%)
- Competitive projects (6%)
- Workshops (1%)
- Training (1%)
- Universities contributions: UDC, USC, Uvigo. (Represents **5%** of the total income of ITMATI.)
European Service Network of Mathematics for Industry and Innovation (EU-Maths-IN)

- Members: national or multinational networks of European research groups in Mathematics

- EU-Maths-IN is formed by 13 nodes from 13 different countries

- Sponsors: European Mathematical Society (EMS) and European Consortium for Mathematics in Industry (ECMI)

Smith Institute | Smith Institute for industrial mathematics and systems engineering. United Kingdom.

AMIES | Agence pour les mathématiques en interaction avec l’entreprise et la société. France

KoMSO | Komitee für Mathematische Modellierung, Simulation und Optimierung. Germany.

PWN | Platform Wiskunde Nederland. Nederland.

PL-MATHS-IN | Polish Service Network for mathematics in Industry and Innovations. Poland

HU-MATHS-IN | Hungarian Service Network for Mathematics in Industry and Innovations | Hungary

IMNA | Industrial Mathematics Network for Austria. Austria

SM[i]2 | Sportello matematico per l’industria italiana. Italy

math-in | Red Española Matemática-Industria. Spain
Transfer Areas

- **CAD** (Computer-aided design) & **CAE** (computer-aided engineering). Numerical Simulation.
  - Modelling of industrial, financial and business processes
  - Numerical simulation of models

- **Statistics & Big Data.** Statistical applications to solve industrial problems:
  - Decision-making support
  - Statistical advice and data analysis

- **Optimization**

Services

- Product /Solutions development
- Technology consulting
- R & D & i collaborative projects
- High level scientific advice
- Training courses on demand
- Customized software development

Mathematical Technology for all industrial sectors
Transfer Areas

CAD (Computer-Aided Design)/CAE (Computer-Aided Engineering).

Numerical simulation: Modelling, simulating or predicting the behavior of devices, products, engineering and applied sciences processes.

- Mechanical or structural
- Thermal or thermodynamics
- Manufacturing processes
- Electronics and/or electromagnetics
- Fluids
- Chemical reactions
- Acoustics or vibro-acoustics
- Environmental
- Fluid-structure interaction
- Multiphysics
- Finance.

Training of new professionals through the Master in Industrial Mathematics

Project solidification of parts in casts. MA1 Group, Uvigo/ITMATI
**Numerical solution of PDEs**

- Finite Difference Methods
- Finite Element (FEM y XFEM)
- Finite Volumen Methods
- Boundary Integral Methods (BEM)
- Reduced Order Methods

**Numerical Simulation**

**Modelling and numerical simulation**

- Linear and non-linear analysis EDPs
- Control problems
- Optimization
- Inverse Problems
- Numerical algorithms to simulate industrial problems
Transfer Areas

Statistics and Big DAta

- Quality control
- Risk & financial analysis
- Customer/market/product studies
- Exploitation of internal information: data mining, business intelligence.
- Experimental design, clinical analysis, etc....

Training of new professionals through the Master in Statistical Techniques

- Financial Risk Analysis for 15 Spanish entitites. Grupo MODES
Transfer Areas

Optimization

It combines numerical simulation techniques, statistics and operations research.

- Optimization of products, production processes and stocks
- Strategy, decision, logistics and planning
- Route planning
- Work planning
- Optimization of resources and their location
- Allocation and optimization of resources and industrial processes
- Optimal decisions support
Statistics and Operations Research (ST/OR)

- Classification and prediction
- Imputation Techniques
- Prediction Statistical Techniques
- Statistical Resamples
- Neural Networks
- Multivariate Statistical Analysis
- Functional Data

- Analysis and Design of Experiments
- Linear and Logistic Regression Methods
- GLM Methods

- Operations Research Models
- Decisions making in complex decisions

Spatial and Space-time Statistics

- Statistical Analyse of Space Data
- Time Series
- Space-Time Methods

Design development and analysis of surveys

Probabilistic methods and techniques of statistical inference

Optimization Techniques

Quality Control
Transfer Areas

Transfer Areas (%)

- Simulation: 25.00%
- Statistics and Big Data: 14.87%
- Optimization: 60.13%

Transfer/Technology Areas in projects/contracts in ITMATI active in 2014 (%). (Calculated in % over the total amount of the project).

Distribution of the number of active projects/transfer contracts in ITMATI in 2014, breakdown by Transfer/Technologies Areas (Some projects are counted in more than one technology)
Transfer Areas

Technological capabilities in projects/transfer contracts of ITMATI

- Location
- Decision-making
- Strategy, logistics and planning
- Optimization of Industrial and Business Processes
- Optimization of Resources
- Production, processes and stocks optimization
- Exploitation of internal information: data mining
- Risk and Financial Analysis
- Reliability and Quality Control
- Finance
- Environmental
- Combustion
- Chemical Kinetics
- Fluids: gases, liquids
- Electronic and/or Electromagnetic
- Thermal and thermodynamic
- Mechanical or Structural

Technological Capabilities in Optimization
Technological Capabilities in Statistics and Big Data
Technological Capabilities in Simulation

Technological Capabilities in Projects/Transfer Contracts in ITMATI active in 2014 (%). (Calculated in % over the total amount of the project.)
Industrial Sectors

Projects/ transfer contracts (%)
(Breakdown by type of Industry Sector)

- Energy: More than 20%
- Materials: 5%-20%
- Others: Less than 5%

Industry Sectors in Projects/ Transfer Contracts in ITMATI active in 2014 (%). (Calculated in % over the total amount of the projects).
Metal & Machinery

- Simulation of metallurgical electrodes.
- Numerical simulation of induction furnaces.
- Numerical simulation of metals and ferroalloys casting.
- Numerical simulation of electrolytic cells.
- Purification processes in the Silicon industry.
- Extrusion and lamination processes.
- Simulation of manufacturing processes: tamping, forging, etc.
- Mechanical calculations for the identification of cracks and fractures.
- Development and implementation of NVH systems for reducing noise and vibrations.
- Simulation of electronic devices.
**Energy**

- Computational Fluid Dynamics (CFD).
- Numerical simulation of heat transfer and combustion processes
- Applications in energy installations:
  - numerical simulation of combustion in coal and oil boilers
  - prediction of breaks
  - pyrotechnic pasta combustion
  - characterization of thermal groups
  - modeling and simulation of oxy-combustion in pulverized coal flames
- Maps of wind and wind power potential studies
- Economic feasibility of wind farms
- Management models of mixed energy systems
- Optimization of power distribution networks
Environment

- Computational Fluid Dynamics (CFD).
- Statistical models for environment and analysis of spatial data.
- Control and calculation of emissions.
- Prevention and control of environmental pollution.
- Simulation and prediction of air and water quality.
- Dispersal of pollutants.
- Dam break, river dynamics, sediment transport.

Average concentration levels of Nickel in moss. modestya Group, USC.

Concentration of Escherichia coli in the Ria de Vigo. GSC Group, UVigo.
Logistics & Transport

- Optimization of resources.
- Location of services.
- Logistics and planning work.
- Production planning.
- Transportation planning and route optimization.
- Vehicle traffic analysis.
- Fleet optimization.
- Management and distribution of goods.
Automotive & Aeronautical

- Active and passive control of noise.
- Acoustic and vibro-acoustic calculations.
- Numerical classification of burns from airbags.
- Calculation of aerodynamic coefficient. Numerical simulation of air flows around vehicles in paint booths.
- Thermo-hydrodynamic analysis of axial and radial bearings for ship propulsion systems.
- Analysis of efficiency and reliability of ships.
- Numerical characterization of materials.
- Thermo-mechanical behaviour of heat exchangers.
- Piezoelectric materials.
Construction

- Calculation of structures.
- Simulation of noise reduction barriers. Thermal and acoustic insulation.
- Vibration of structures.
- Numerical characterization of insulating, lightweight and thermal materials.
- Numerical characterization of resistance of materials.
- Numerical simulation of ventilated façades.
- Statistical assessment for quality control.
- Behaviour of new materials.
- Software to optimize stone cutting.

![Tensions of a cylindrical beam](image1)

![Temperature of a cylindrical beam](image2)

**mat+i Group, USC.**
Economics & Finance

- Analysis and prediction of interest rates. Quantitative finance.
- Development of internal models of measurement, management and control.
- Evaluation and optimization of flows in portfolio assets and liabilities and financial products.
- Measurement of financial and operational risk.
- Stochastic modelling of accident rate.
- Market studies and quality of services.

Valuation of financial derivatives. M2NICA Group, UDC.

Financial risk analysis for 15 Spanish institutions. MODES Group, UDC.
Biomedicine & Health

- Biostatistics
- Analysis and design of experiments and clinical trials
- Studies of efficacy and safety of treatments
- Statistical analysis in epidemiology
- Tables of life expectancy
- Modeling of mortality tables.
- Biomechanics Simulation. Bones formation.
- Numerical simulation of fractures, dental implants and orthodontic brackets.
- Quality control and optimization of products, processes or resources in health management

Detection of false positive in mammograms. modestya Group, USC.

Stresses in a human jaw. MOSISOLID Group, USC.
Agriculture & Food

- Logistics of agricultural machinery.
- Effectiveness of pesticides. Maps of epidemiological risks.
- Market studies.
- Control and optimization of products and processes.
- Production planning.
- Allocation of products to customers.
- Sterilisation of food.
- Analysis and optimization of the sterilization processes of canned food.
- Shelf life of foods.

Microwave thawing applied to defrost food in industrial processing. Temperature. mat+i Group, USC.

Microwave thawing. Norm of the electric field. mat+i Group, USC.

Maps of risks of weed infestation. modes Group, UDC.
Tourism & Services

- Design, development, analysis and debugging of surveys.
- Statistical analysis of the behaviour of tourism networks.
- Analysis of the habits of the population.
- Analysis of demographic change.
- Studies of job placement.
ICT

- Design of wireless networks.
- Scientific and technical advice on databases.
- Software development solutions on demand.
- Programming on GPUs.
- Management and planning of telecommunication networks
- Design and simulation of electromagnetic devices
- Development of customized software
- Exploitation of databases: business intelligence
- Advice on statistical and scientific databases

Free software for the numerical solution of electromagnetic problems. mat+i Group, USC.
Temperature distribution in a section of the electrode ELSA. mat + i Group, USC.

Simulation of a pulverized coal flame. mat + i Group, USC.

Simulation of sound pressure on a bus. mat+i Group, USC.

Temperature of a cylindrical beam. mat+i Group, USC.

Average concentration levels of Nickel in moss. modestya Group, USC.

Flows air in automobile paint booths. MA1 Group, UVigo.
- Valuation of financial derivatives. M2NICA Group, UDC.
- Free software for the numerical solution of electromagnetic problems. mat+i Group, USC.
- Microwave thawing applied to defrost food in industrial processing. Temperature. mat+i Group, USC.

- Stresses in a human jaw. MOSISOLID Group, USC.
- Maps risk of weed infestation. modes Group, UDC.
Success stories  Aeronautical Automotive

REDUCTION of NOISE and VIBRATIONS in BUSES

**Challenge**

To increase the comfort and reliability of passengers in buses.

**Goals**

- To reduce costs in resources, and in time.
- To evaluate vibro-acoustic properties in new vehicles.
- To reduce noise inside the passengers’ cabin.
- To minimize vibrations supported by the structure of the vehicles.

**Benefits**

The company has a calculation methodology to predict, design and optimize the acoustic behavior of their vehicles.
Sucess Stories
Aeronautical, Automotive and Naval

- Bearing for ship propeller in maneuver tunnel

The advantage of using numerical simulation to assess the viability of the operation of these pieces is that if the results had been disastrous, the company would have prevented build a prototype and therefore have secured a huge saving in cost.

Lubricated support bearings, axial and radial, to a rotary machine.
Success stories
Metallurgical

- Optimizing the design and operation of metallurgical electrodes.

Distribution of current density and temperature in a section of the ELSA electrode.

Distribution of the maximum principal stress in the nipple area.

The software package “ELSATE” allows to know the distribution of current, temperature and mechanical stress in a radial section of a metallurgical electrode.
Success stories
Metallurgical

OPTIMIZATION OF THE PROCESS FOR SILICON PRODUCTION.

Performing these experimental trials was too expensive, and numerical simulation allowed the study of the problem even before the acquisition of the oven.

THESIF software has been registered by the research group and is free to the scientific community.

Temperature distribution in an induction furnace.

mat+i | USC
FerroAtlántica I+D
8 years (2003 – 2011)
Sucess Stories
Metallurgy

- Temperature control in an industrial furnace.

This solution enables a significant saving in the gas consumption of the burners, estimated at 15%, which in a microwave of these characteristics that consumes a million euros in gas a year, is a very important saving.

Gas temperature distribution in the furnace chamber
SUCESS STORIES
SUCESS STORIES
Energy

JOINT RESEARCH UNIT (JRU) REPSOL-ITMATI

Research on mathematical and numerical methods for solving problems found repeatedly in the daily activity of Repsol, especially in the field of simulation and optimization of devices and processes.

Research lines covering the JRU:
- Increase the useful life of the batteries that electric vehicles use.
- Improve the process of rapid recharge.
- Incorporate in the decision making processes in production planning in industrial plants the uncertainty in prices, demand and quality of raw materials and products.
- Inferring complex and rigorous models of physical and chemical phenomena from a small number of observations.

Alfredo Bermúdez de Castro
REPSOL
Success Stories
Energy

- GANESO: SIMULATION AND OPTIMIZATION OF GAS NETWORKS

Development of a software tool for the simulation and optimization of gas networks. It allows the user to obtain, in an interactive way, the optimal distribution of flows based on different criteria, the calculation of tariffs, the transients simulation and planning of network extensions under uncertainty.

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

Alfredo Bermúdez
Julio González
Reganosa
2011-present
Success stories
Energy and Environment

**ANTICIPATION OF POLLUTION INCIDENTS**

This SOFTWARE, known as SIPEI, allows users to obtain predictions of the values of sulfur dioxide and nitrogen oxides half an hour in advance. So, one can predict a possible pollution incident.

Map of the hourly average concentration of SO2 in the environment of the As Pontes Power Plant (historical incident)
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. ITMATI has made a statistical model to characterize the operational profile of energy demand of the target ships.
Sucess Stories
Environment, Air Logistics

ADVANCED TECHNOLOGIES FOR EXTINCTION OF LARGE FOREST FIRES.
LUMES PROJECT

Development of an expert system for monitoring and managing the resources involved in extinguishing a fire and to help in decision-making by those responsible:

- efficient and safe system of coordination of air traffic in real time.

- allows the management of air assets in their distribution within the scene of fires and their operating instructions

+ Info:
Success Stories
ICT | Economics and Finance

- PREDICTING the NUMBER of CLAIMS and their COST

Information about the total cost of claims that will occur in a given time based on the information about the claims incurred in the last period.

The AG.LOSS tool developed by the group MODES was used by the Risk Management department of Inditex Group to help define the risk policy of the Group and estimate, using simulation techniques, the expected results.

Approximately 1 year in two stages (2005 y 2007)
Sucess Stories
Agrarian Logistics

PLANNING HARVESTING ROUTES IN AN AGRICULTURAL COOPERATIVE

Automation and route planning aimed at minimizing costs and considering various restrictions of customers:
- A binary linear programming model was introduced.
- A JAVA application that implements the resolution algorithm was designed.

Tabú obtained route algorithm Vs route obtained “manually”

Ignacio García Jurado
Os Irmandiños S. Coop. G. 18 months
X Forum for interaction between Mathematical and Industry

- To raise the potential needs of the Industry and Enterprises in relation to mathematical methods, numerical simulation, statistics and operations research to solve industrial problems.
- To improve the relationship between Companies and Universities in the field of Industrial Mathematics.
- To promote the use of mathematical modeling and numerical simulation, statistical techniques, data analysis, information exploitation, etc., in the industry.
- To open lines of research toward topics of interest to Business and Industry.
- To promote the incorporation of specialized technicians to the industry.

http://www.itmati.com/x-foro-de-interaccion-matematica-industria
Model order reduction for Li-ion batteries simulation at cell scale | Repsol.

Analysis of the influence of the air speed and the temperature in the quality and in the energetic efficiency of the wood drying process for Galician pine. | CIS Madeira (GAIN).

LNG Import Forecasts in Spain. | Reganosa

“The European Study Groups with Industry will contribute to enhance the transfer of mathematical knowledge to industry”

http://www.math-in.net/110aesgi/english/index.html
II Iberian Modelling Week

29 Junio – 3 Julio 2015, Santiago de Compostela

It draws together academic supervisors and industry representatives to work in groups on defined projects and jointly supervised by academic and industrial partners, and thereby discover how mathematics contribute to solving current industrial problems.

http://www.math-in.net/2imw/english/index.html
Director of ITMATI/Full Professor USC
Peregrina Quintela Estévez
peregrina.quintela@itmati.com

Executive Manager
Rubén Gayoso Taboada
ruben.gayoso@itmati.com

Technology Transfer and Innovation Manager
Adriana Castro Novo
adriana.castro@itmati.com

http://www.itmati.com
Modeling and simulation of industrial and business processes

Biostatistics, Processes optimization, Valuation of financial products, Thermomechanical, Quality Assurance, Business Intelligence

Thermo-hydrodynamic and aerodynamic simulations

Energy Efficiency, Renewable Energy: wind, solar, biomass, Vibration of structures

Biomechanics, Propagation and Dispersion of pollutants, Optimization of packaging

Strategy, Decision, Quantitative finance, Non-destructive inspection techniques

Market studies, Quality and food preservation, Epidemiological studies, Logistics and Planning work