ANNUAL REPORT 2020

# 2020

**IIIA-CSIC**
INSTITUT
D'INVESTIGACIÓ
EN INTEL·LIGÈNCIA
ARTIFICIAL

**Annual Report 2020**

IIIA-CSIC Institut d'investigació
en Intel·ligència Artificial

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IIIA-CSIC INSTITUT D'INVESTIGACIÓ EN INTEL·LIGÈNCIA ARTIFICIAL 25 anys 1994-2019

CSIC Consejo Superior de Investigaciones Científicas

# ANNUAL REPORT 2020

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ARTIFICIAL

# Table of contents

# We co-me

# 1

2020 will be remembered as the year of the pandemic. For us, at IIIA, the pandemic represented an opportunity for reflection, out of which this document is a great result. First of all, I want to thank the communication team for the quality of the content herewith provided. In the following pages, you will find some highlights of our researchers' many historical and recent achievements. We have consolidated a human project that started in 1985 as a tiny group of researchers at the CEAB (Centre d'Estudis Avançats de Blanes). Now, we are a thriving institute where 80 researchers, students and administrative personnel, work together to make the science of Artificial Intelligence progress beyond its current limits.

We have contributed to many Artificial Intelligence areas, including machine learning, knowledge representation, multiagent systems, agreement technologies, natural language processing, reasoning, optimisation, and semantics. You will see our current work in the descriptions of active research projects. We have weaved a significant international network of contacts. As part of that, most of our 100 alumni hold relevant research and industrial positions worldwide, in Australia, US, France, UK, Singapore, Italy, and Argentina, to name a few. As part of our achievements, we have led over a hundred research projects on AI's fundamental aspects and applied our theoretical results to many different domains like education, health, or manufacturing. Moreover, IIIA is an active player in the Catalan industrial ecosystem, participating in many technology transfer projects and supporting spin-off companies' creation.

**CARLES SIERRA**
Director

We are proud to be a scientific referent in AI with more than 3000 publications since 1985 and to be a reliable contributor to AI management efforts. For instance, as active editorial board members of the leading journals of the area (AIJ, JAIR, JAAMAS, Fuzzy Sets and Systems), as members of scientific boards (IFAAMAS, IJCAI Board of trustees, EurAI), or as conference organisers (IJCAI-2007, -2011, -2017, AAMAS-2004, -2009). The international community of AI knows that they can count on us as a vital ally to achieve excellence in research.

I invite you to browse this document to understand the history and achievements of IIIA better.

IIIA-CSIC Institut d'Investigació en Intel·ligència Artificial 25 anys 1994-2019

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# About IIIA

The Artificial Intelligence Research Institute (IIIA) belongs to the Spanish National Research Council (CSIC).

It is a leading research centre in AI in Spain and Europe, maintaining the right balance between basic research and applications.

It pays particular attention to training PhD students and technology transfer. Since 1987, the IIIA scientists have supervised 100 PhD students.


Since 1994, the IIIA-CSIC has been located on the campus of the Universitat Autònoma de Barcelona.

The IIIA currently has 81 full-time researchers and engineers (including 27 senior researchers and 29 PhD students). The IIIA has three primary research lines: logic and reasoning; machine learning; and multiagent systems. The institute has three departments, one for each research line, and a Technological Development Unit (UDT-IA) devoted to technology transfer in the industrial ecosystem and to bring IIIA research results to society.

# Our Organization

### DIRECTION

The Director (Carles Sierra) is the head of the institute, assisted by the Deputy-Director (Felip Manyà) and the Manager (Àngels Benet/Marta Vendrell)

### EXECUTIVE BOARD

The executive board is a body that advises and informs the Director in all those matters that affect the institute's functioning. The Director is the president of the executive board, and the board is composed of the deputy-director, the manager, the three department heads, and three elected representatives of the personnel.

DEPUTY-DIRECTOR
- Felip Manya

### DIRECTOR
- **Carles Sierra**

MANAGER
- Àngels Benet
- Marta Vendrell

### SCIENTIFIC BOARD

The scientific board is the forum of discussion of scientific matters. The board's president is the Director and it is composed of all the tenured scientists.

## STEERING COMMITTEE

The steering committee comprises people responsible for strategic topics: web and social communication, projects, contracts, students and education.

- COMUNICATION
  - Josep Puyol-Gruart
- PROJECTS
  - Josep Lluís Arcos
- CONTRACTS
  - Pere Garcia
- STUDENT RECRUITMENT
  - Marco Schorlemmer
- SEMINARS & FORMATION
  - Jordi Sabater
- WEB
  - Nardine Osman

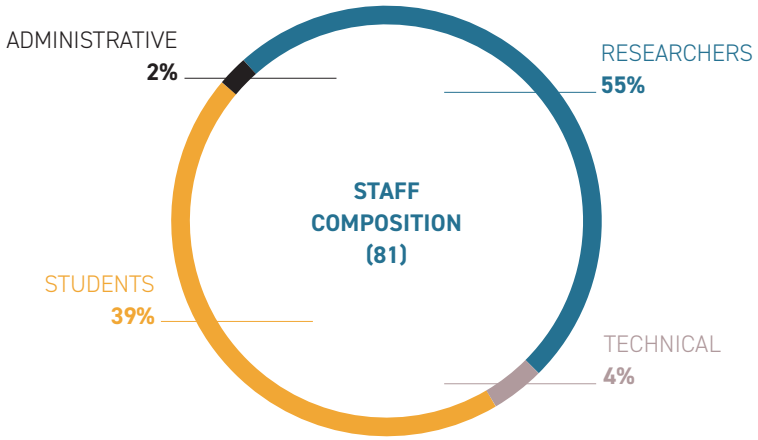
## DEPARTMENTS & UNITS

The IIIA has three departments: Machine Learning, Multiagent Systems and, Reasoning and Logic, along with the Technological Development Unit (UDT-IA).

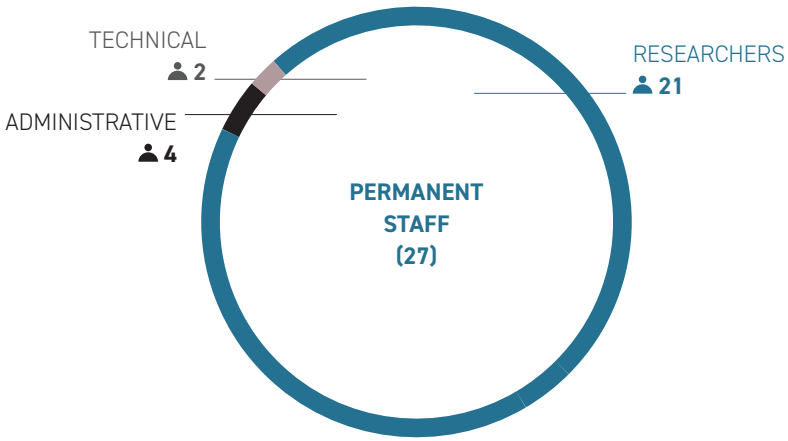
- LRS DEPT.
  - Head - Pedro Meseguer
- ML DEPT.
  - Head - Josep Lluís Arcos
- MAS DEPT.
  - Head - Marco Schorlemmer
- UDT-IA
  - Head - Pere Garcia

- LIBRARY SERVICES
  - Laura Cester
- ADMINISTRATION
  - Montse Santmartí
  - Eva Llavería
- IT SERVICES
  - Evili del Rio
  - Bea Hernández

# 2020: Personnel and Funding

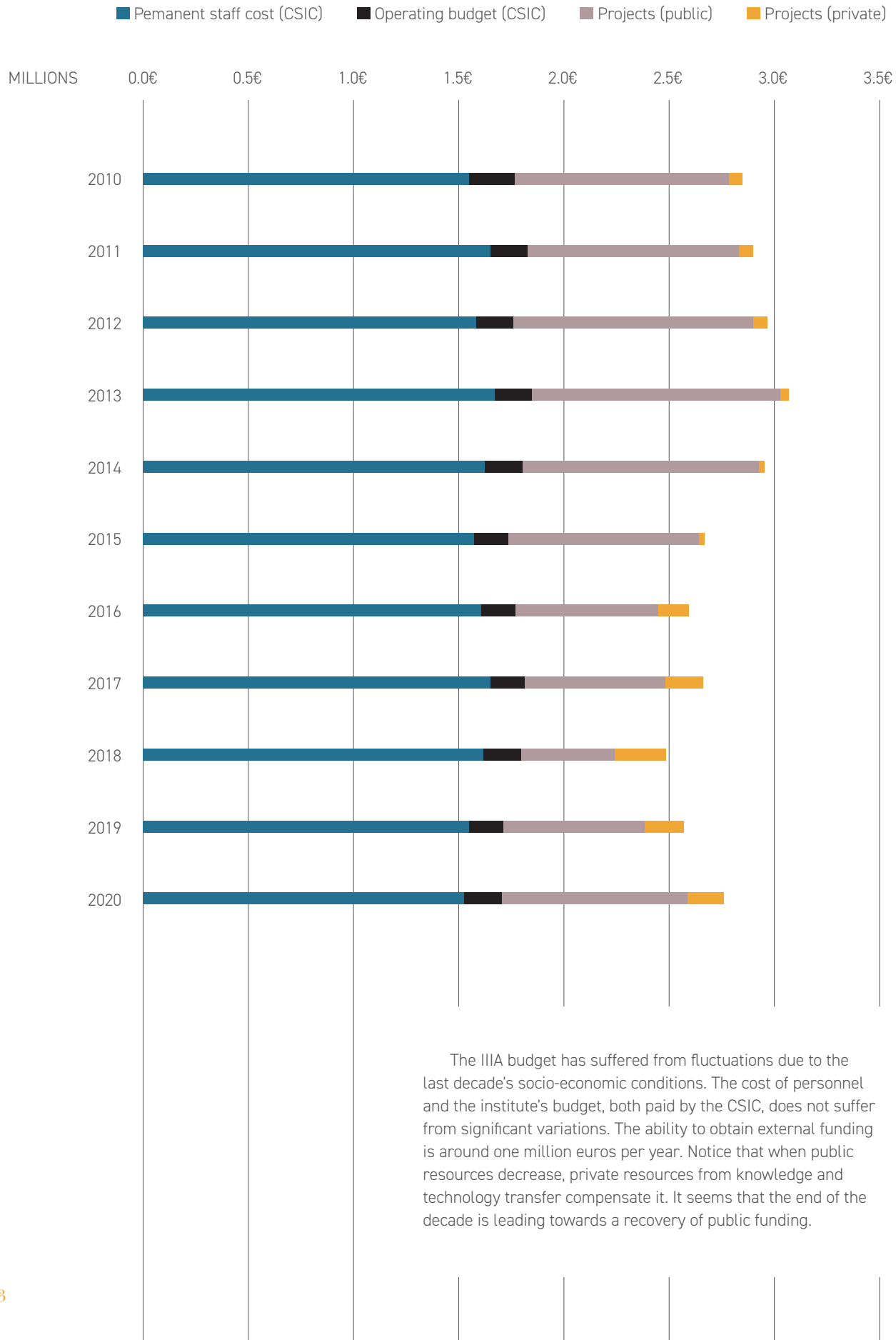



The IIIA staff are primarily scientists and students, plus administrative and technical support staff. 50% of the scientific staff are permanent. Students are the foundation for the future of IIIA and AI in general. At the moment, we have 22 doctoral students and 5 master's degree students.



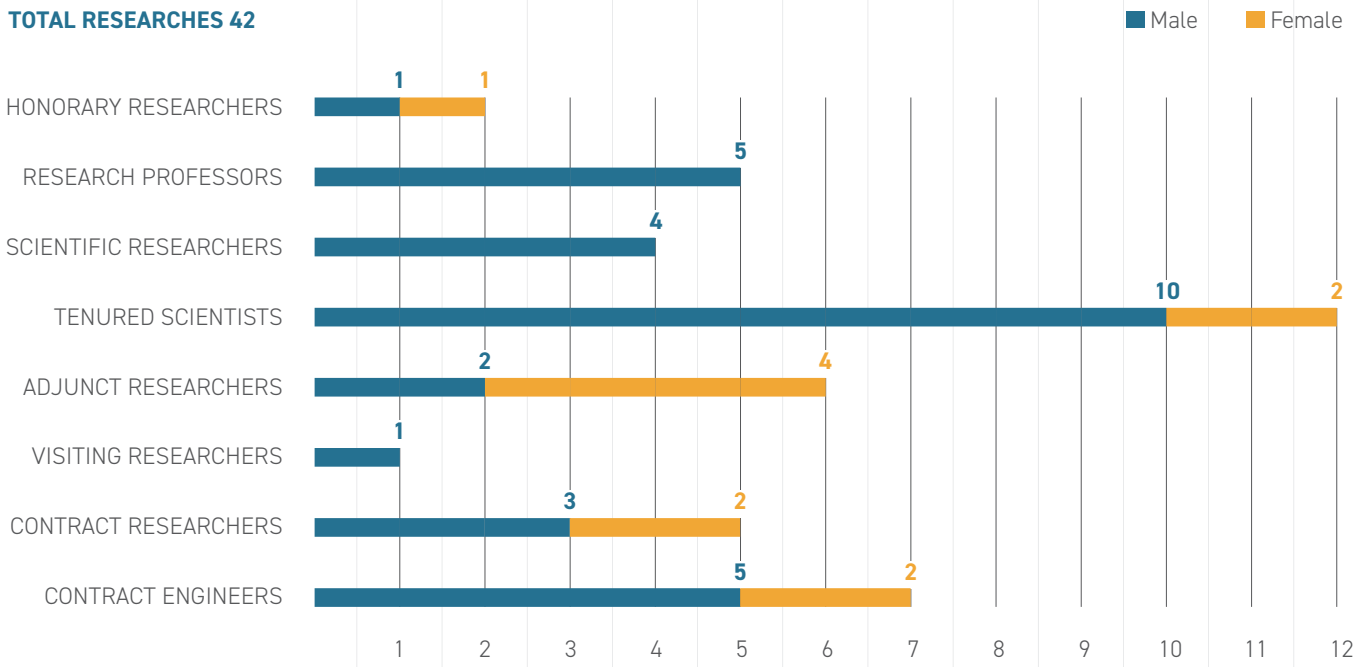

Of the 81 people who are part of the IIIA in 2020, 37% are permanent CSIC staff. Most of these 27 people are researchers (21), and the rest are technical IT personnel (2) and administrative personnel (4). The proportion of permanent scientific staff with respect to the total has decreased due to the new forms of recruitment and scientific policy, and at this moment it represents 50%.

## TOTAL IIIA BUDGET

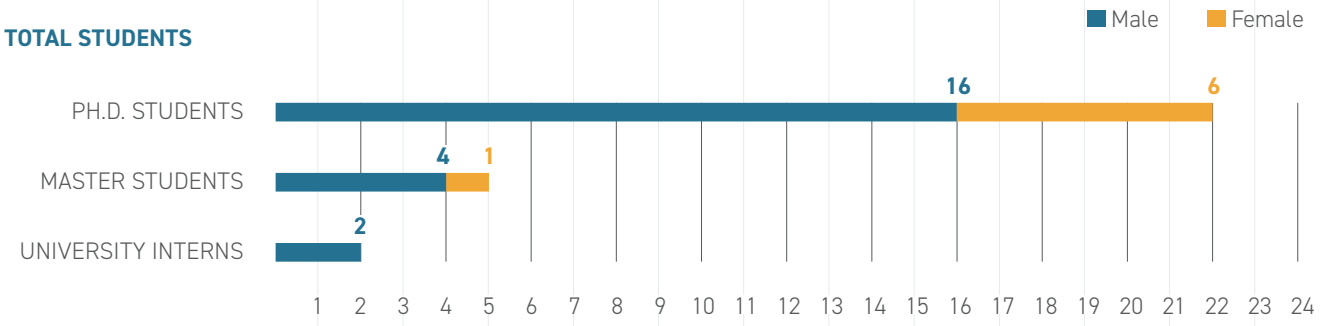



The IIIA budget has suffered from fluctuations due to the last decade's socio-economic conditions. The cost of personnel and the institute's budget, both paid by the CSIC, does not suffer from significant variations. The ability to obtain external funding is around one million euros per year. Notice that when public resources decrease, private resources from knowledge and technology transfer compensate it. It seems that the end of the decade is leading towards a recovery of public funding.

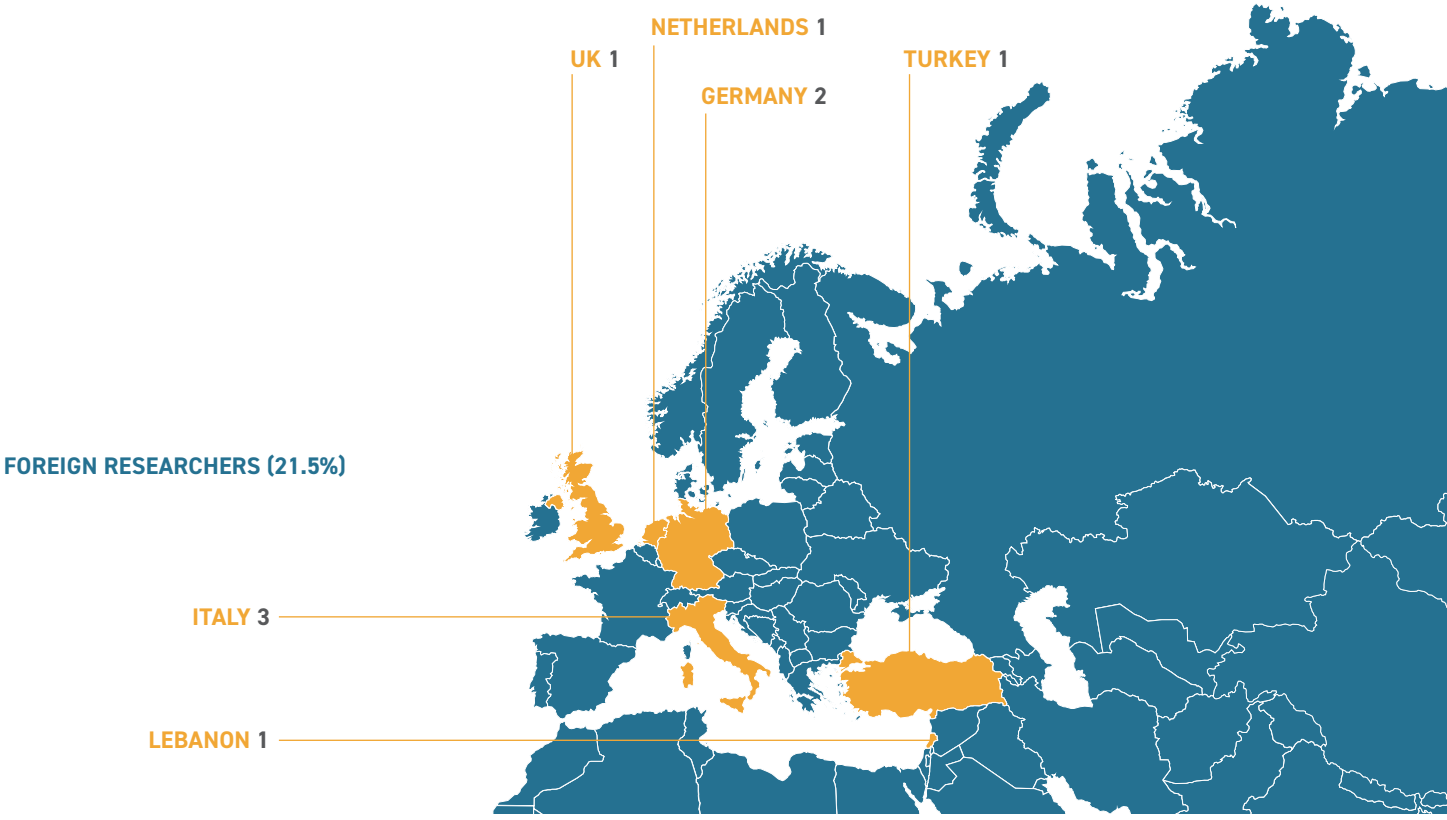
# 2020: Researchers and students, the essential balance




Research Professors, Scientific Researchers and Tenured Scientists are the permanent staff of the CSIC, comprising 50% of the total IIIA staff. Usually, we have at least one visiting researcher who is on sabbatical, which is essential for new ideas and provides a critical external view of our work. Contract researchers support the permanent staff with their research projects. Contract engineers are vital to technology and knowledge transfer.




IIIA researchers have supervised 100 theses, and there are currently 29 active PhD students. We also have Master's students who may be candidates for PhD studies in the future, and we accept university interns who may have a future in research.



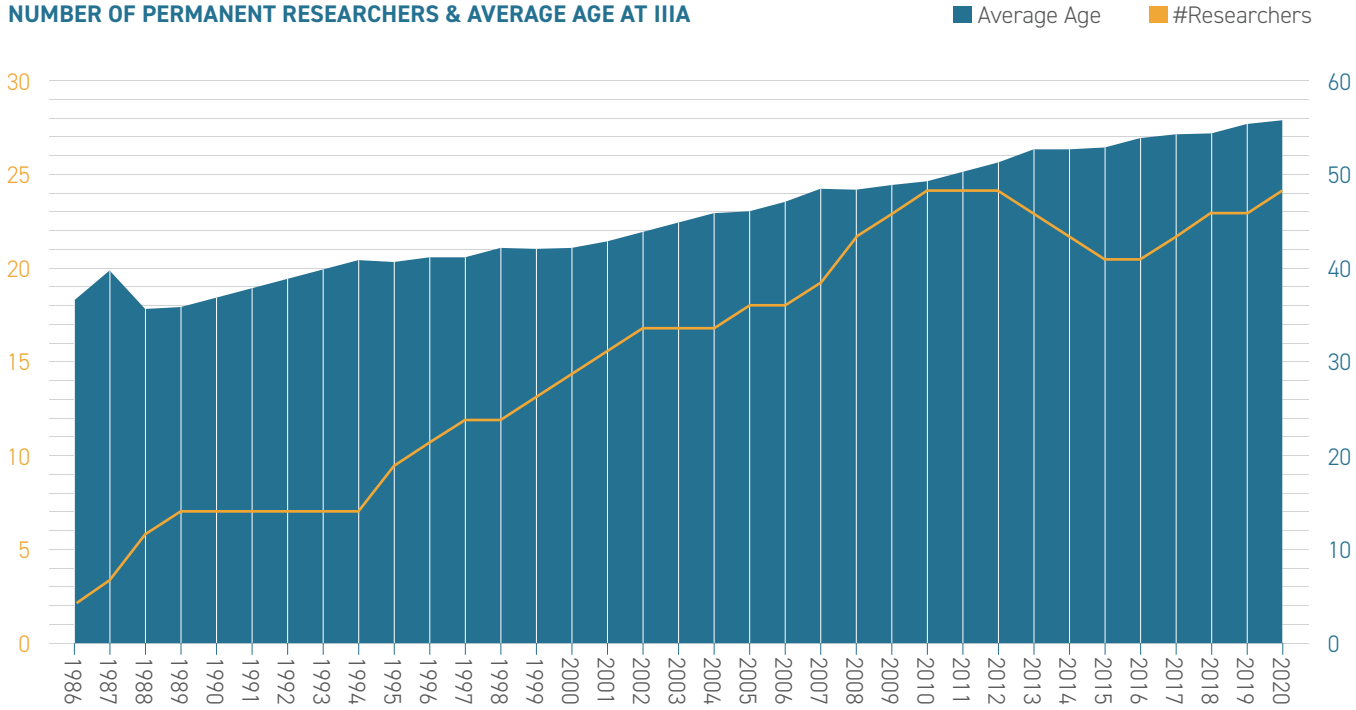

### Open to the world

We are very proud to have more and more foreign researchers every year. They form 21.5% of the total personnel, with 4 of them permanent CSIC researchers. Almost 40% of our students are also foreigners.

### Personnel and gender

30% of the staff are women, which is within the normal parameters in the technological environments today. The IIIA has an active policy with the intention of improving these ratios.

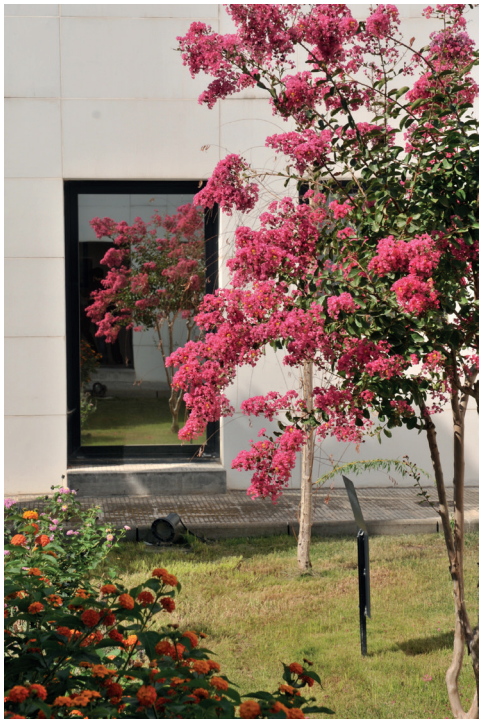
### NUMBER OF PERMANENT RESEARCHERS & AVERAGE AGE AT IIIA

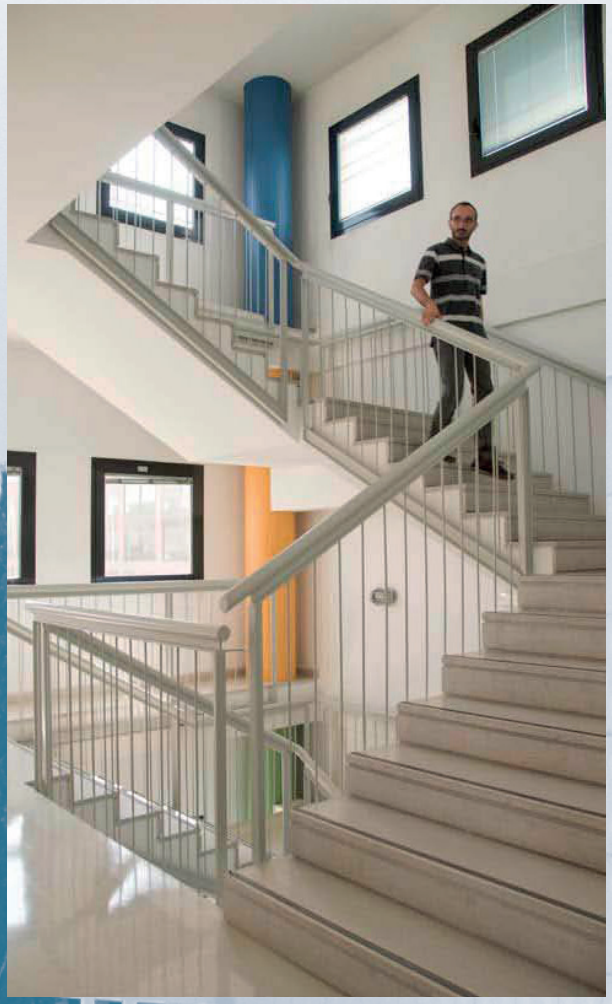


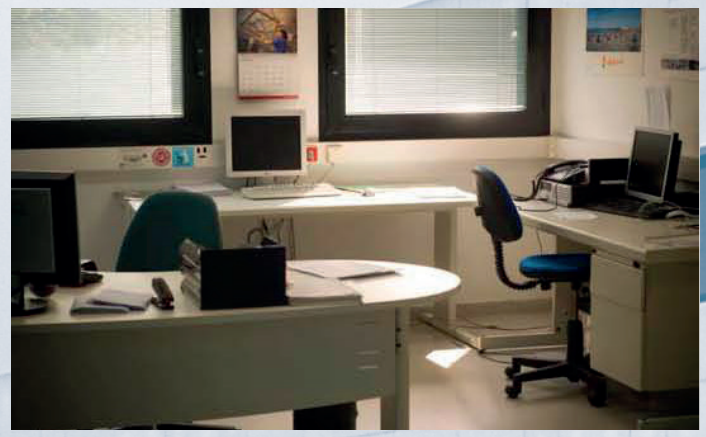

### The importance of students

Students are the new blood of research. Without them, scientific continuity would be impossible. At IIIA, we take great care of our students. In the graph above, you can see the evolution of permanent researchers' growth and ageing during the last decade. As you can see, we need to act to rejuvenate the institute urgently. We are working hard to do so with a new generation of PhD students and postdocs. At the same time, we are looking for opportunities to attract young global talent.

# Our Institute

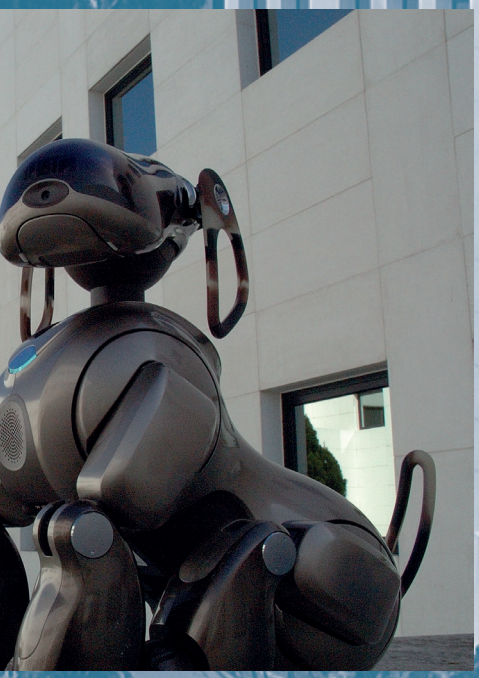






IIIA-CSIC

INSTITUT D'INVESTIGACIÓ EN INTEL·LIGÈNCIA ARTIFICIAL



The IIIA building is a 2 storey building. The administrative services, a library, a dining room, a seminar hall with a capacity of 90 people, and a fully equipped meeting room for ten people are all located on the ground floor. The first floor consists of researchers' individual offices, a dedicated doctoral students room that can host up to 12 students, and a UDT room that can host up to 12 engineers. The second floor also hosts individual offices, along with a second and larger meeting room that can accommodate up to 15 people, a room for startups that can accommodate up to 12 people, and a computer infrastructure room, including our Ars Magna cluster. The building has an open cloister at its centre, which consists of a patio with a garden along with a couple of terraces on the first floor.


**IIIA-CSIC**
Institut d'investigació en intel·ligència artificial

# We need computing power


### ARS MAGNA: The IIIA cluster

The high-performance computing service for AI consists of a high-performance and high-availability computing cluster. It comprises 5 computing nodes with 2 Intel Xeon 4210 processors at 2.2GHz with 10 cores, 20 threads and 96Gb of RAM memory; 2 management nodes with Intel Xeon 4210 2.2GHz processors, with 10 cores, 20 threads and 128Gb of RAM and one storage server. Besides, it has 2 Asus Geforce Turbo RTX 2080Ti GPUs and 11Gb of RAM.

Our mission is to make this computing capacity available to researchers and projects that need Artificial Intelligence (AI) techniques to meet their challenges and require computing and memory capabilities beyond the reach of conventional computers. Scientists can also take advantage of the parallel computing capabilities provided by this service.

We also provide different open-source libraries of AI tools such as Pytorch, TensorFlow, Scikit-learn or Keras, and specific tools and utilities developed at IIIA.

The service is in charge of highly qualified AI researchers and technicians, which will help get the most out of the infrastructure and available software and, if necessary, develop customised software for R&D projects.

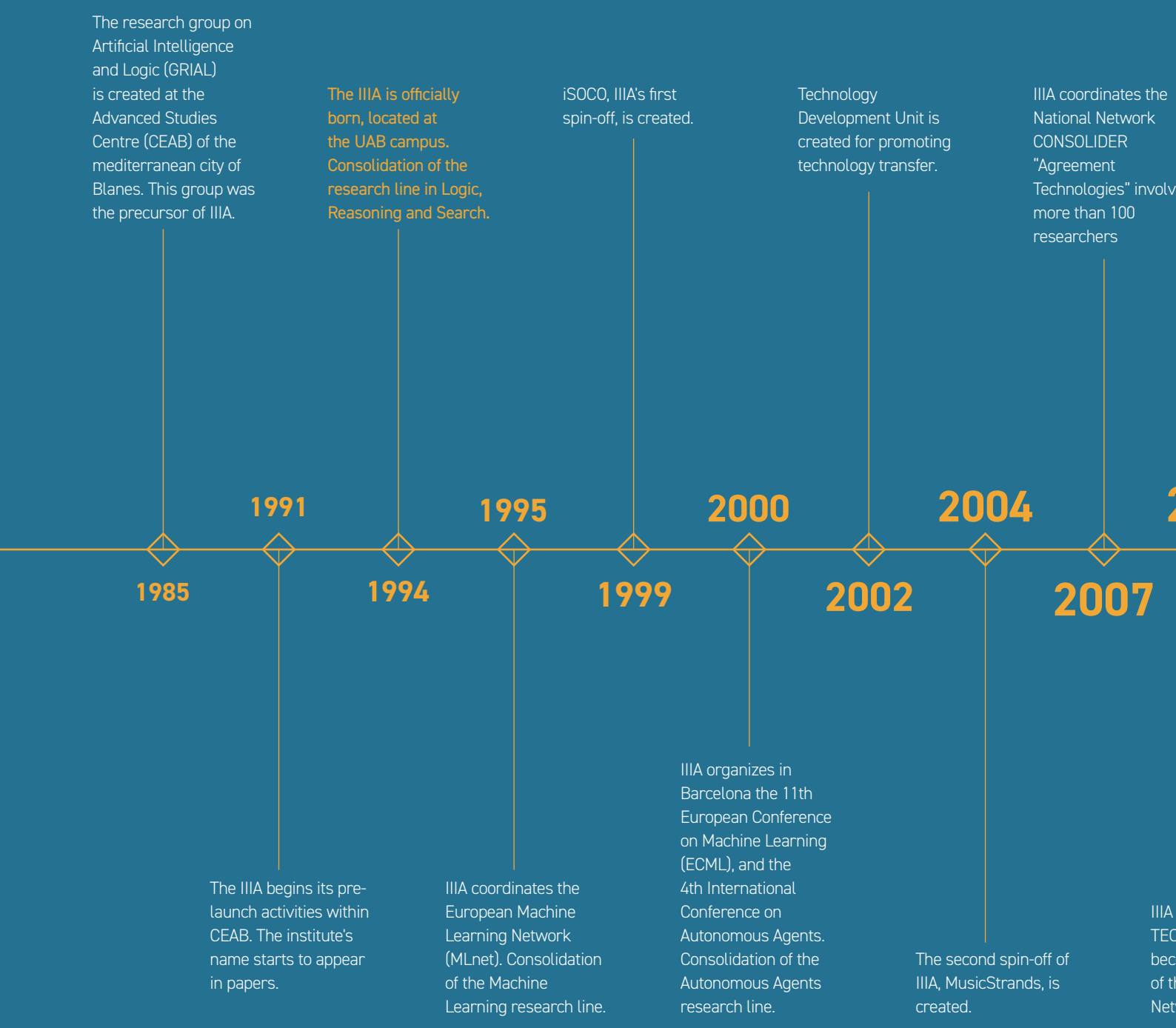
### This service is especially indicated in:

- The development of Machine Learning models that require large amounts of data.
- The development of applications that require the resolution of optimisation problems.
- The development of applications that require distributed computing, such as multi-agent systems.
- The development of applications that require intensive testing to verify their efficiency.
- Empirical research, taking advantage of its ability to abort and launch experiments more dynamically and flexibly.
- The study of AI algorithms' behaviour and performance, since we have a homogeneous infrastructure of machines that allows us to ensure the same hardware conditions for experiments.

### In tribute to Ramon Llull

Ars Magna is our cluster's name, honouring the lay philosopher Ramon Llull (1232-1316), a precursor of artificial intelligence. His Ars Magna Generalis (1274) was the most extended version of a logic-based method, supported by a (simple) mechanical device, underpinning formal argumentation. Ramon Llull's works influenced Gottfried Leibniz and modern science, including computing and artificial intelligence. Apart from logic-based reasoning methods, we can also find traces of other current AI concepts in his works, like semantic networks or heuristics

# Our history at a glance



ing

receives the
CNIO seal and
omes a member
he Technological
work of Catalonia.

2009

2011

IIIA organizes the "International Joint Conference on Artificial Intelligence" (IJCAI). 1500 researchers visit Barcelona to present their work.

2012

Cognicor, a new spin-off of the IIIA, is created.

2013

The IIIA reaches a record number of 7 members being Fellows of EurAI.

2014

Creation of WWWOOOWWW, the fourth spin-off of IIIA.

2016

IIIA becomes a Certified New Technology Developer of TECNIO

2017

IIIA is a co-promoter of the Barcelona Declaration for an Ethical Investigation in Artificial Intelligence. Consolidation of the Responsible AI research theme.

2018

Ramon López de Mántaras, IIIA director, receives the National Research Award "Julio Rey Pastor" in Mathematics and ICT.

2019

IIIA participates in key European research projects on Artificial Intelligence: AI4EU & Humane-AI-Net.

# 25th anniversary celebration

**Remembering the origins of IIIA**
- Jaume Agustí
- Francesc Esteva
- Ramon López de Màntaras (moderator)
- Settimo Termini
- Josep Aguilar

IIIA is a leading artificial intelligence research laboratory in Spain that belongs to the Spanish Council for Scientific Research (CSIC). All started in 1985 when the president of the CSIC, Prof. Trillas, commissioned Ramon López de Mántaras to create an AI group at the CEAB with a few graduate students and with the help of Jaume Agustí, Josep Aguilar-Martín (on leave from the CNRS), and Settimo Termini (on leave from the CNR). It was created in 1985 out of the AI research group at the CEAB in Blanes. Since 1994, IIIA has resided at the the campus of the Autonomous University of Barcelona.

*Why superintelligent AI will never exist*
Suggestive title of the excellent conference of Luc Steels (ICREA researcher), old friend of IIIA, a gift for us.

### 25th anniversary of IIIA celebration December 19, 2019

We celebrated the IIIA's 25th anniversary on December 19, 2019. The event consisted of two round tables on the history and the future of IIIA and a lecture by Professor Luc Steels, followed by a lunch. We want to thank all the people, colleagues and friends, who have made all these exciting years of science possible and who have paved the way for a future full of optimism.

# Our friends: Testimonials

**Selected phrases of our good friends**

Colleagues and friends of IIIA worldwide agreed to participate in a video where they expressed their testimony of the first 25 years of the IIIA.

**Piero Bonissone,**
a colleague who spent a sabbatical at IIIA 25 years ago ⟶ Also former Chief Scientist Analytics at General Electric Research, USA, and founder of Piero Bonissone Analytics

*"In 1995 I spent with Paola and Stefano the best year of our life in Barcelona, at the 'Instituto', on a sabbatical, and I want to thank Ramon for making it happening. So, then I went back to GE, who cares, the important thing is that I moved to San Diego when I retired to be close to Stefano and my grandkid. So I'm playing full-time grandpa and part-time consultant, and now that the Instituto is celebrating its 25 anniversary I want to wish all my friends and the Instituto the very best. Salut! Cheers!"*

**Francisco Martín,**
a IIIA alumnus with an extreme passion for transforming the world ⟶ Also Founder and CEO de BigML, Strands and iSOCO.

*"Muchas gracias a Enric Plaza por aceptarme dos veces como doctorando, a Ramón y Francesc por apoyar mis iniciativas. ISOCO, STRANDS y BIGML no hubieran existido sin su apoyo."*

*(Many thanks to Enric Plaza for accepting me twice as a doctoral student and Ramón and Francesc to support my initiatives. ISOCO, STRANDS, and BIGML would not have existed without your support)*

**Sindhu Joseph,**
a brilliant IIIA alumnae with a desire to apply AI in the real world ⟶ Also founder & CEO, Cognicor Technologies, USA-Spain.

*"I had a great time doing my PhD, and it will always be a place very deep to my heart."*

**Simeon Simoff**,
a good friend of the institute building bridges with down under —⟐ Also Dean of the School of Computing, Engineering, and Mathematics, Western Sydney University, Australia.

*A lot of boomerangs have flown between Sydney and Barcelona, and also a lot of research questions were asked, and some answers were found.*

**Mark d'Inverno**,
an extremely creative scientist with whom we have worked on many exciting projects —⟐ Also Professor and Pro-Warden International Goldsmiths, University of London.

*Singing happy birthday with his piano in the key of jazz.*

**Mike Wooldridge**,
a great scientist in love with Barcelona and always ready to collaborate with us —⟐ Also Professor and Head of Department of Computer Science, Oxford University.

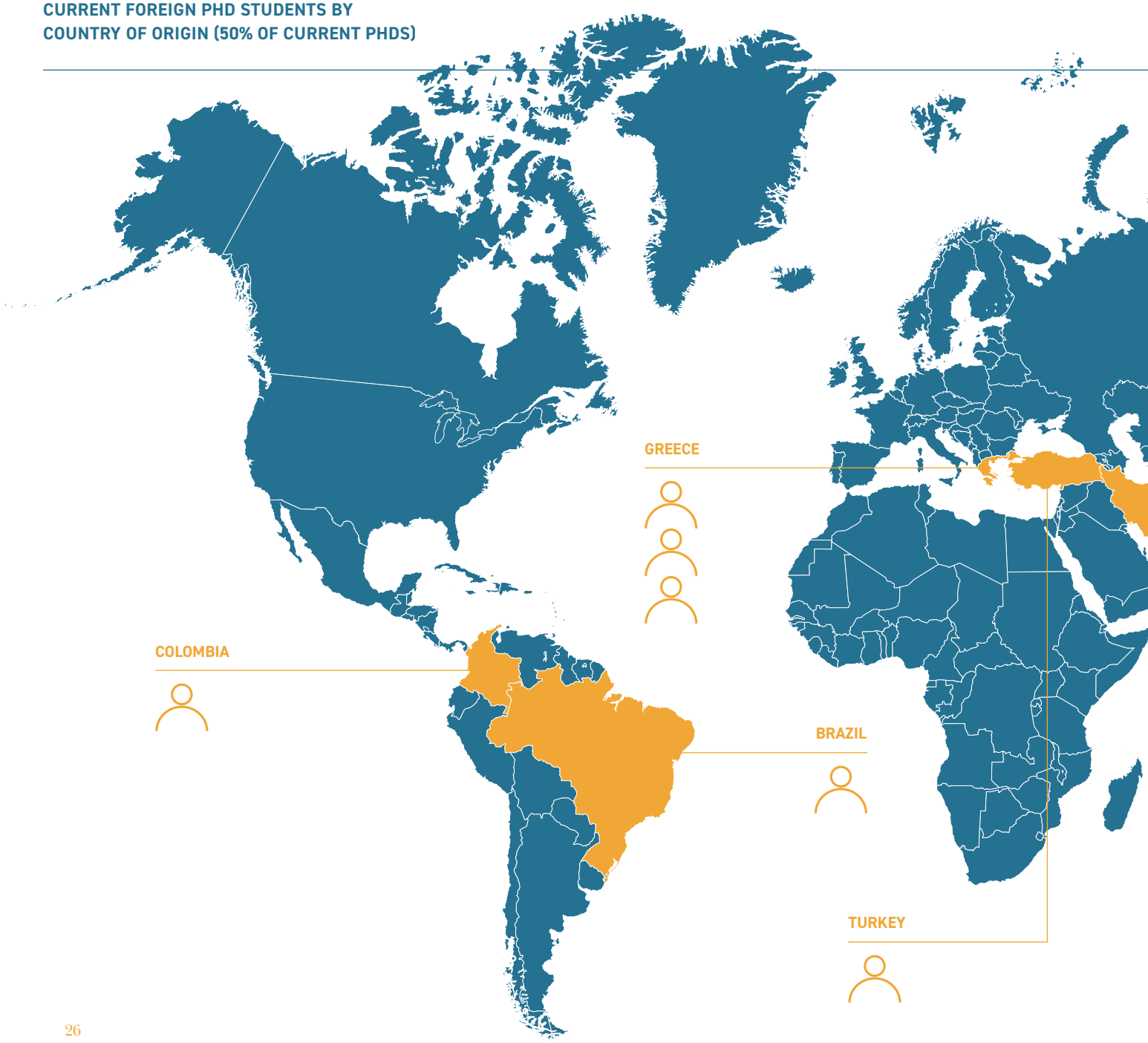
*Science is great. Many cool things are happening all across the lab, but it is the people of the lab who make it so special.*

**Mike Luck**,
a good friend of IIIA that never says no to any of our requests —⟐ Also Professor and Executive Dean Faculty of Natural and Mathematical Sciences King's College London, UK.

*I'm delighted to be video messaging you with my best wishes for the anniversary of the institute. I have so many fantastic experiences over there that is hard to pick something to tell you about, but I think my favourite is 15 years ago when I spent a short sabbatical over there and I stayed above the Bagdad club, I celebrated that fact in the Xmass celebration where I sang together with colleagues' La Cucaracha'.*

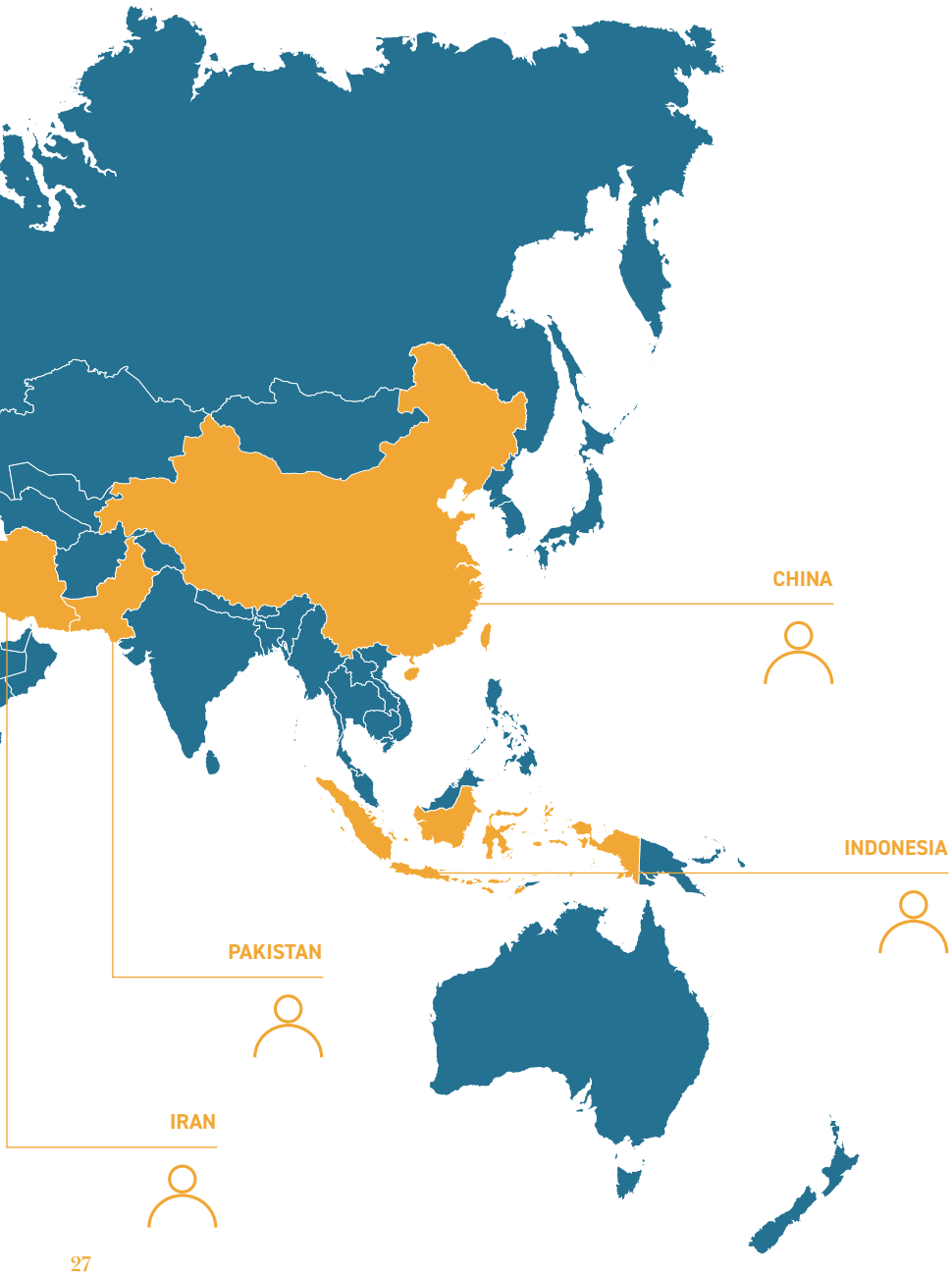
# We are aware of inequalities, we consciously fight against discrimination

**CURRENT FOREIGN PHD STUDENTS BY COUNTRY OF ORIGIN (50% OF CURRENT PHDS)**



69% — IIIA PERSONNEL BY GENDER — 31%

70% — CURRENT PHD STUDENTS BY GENDER — 30%




### We are proud of our students

It has been shown that diversity helps produce stronger research.

We cannot do science from a single point of view. With IIIA's commitment to the II Plan of Equality between women and men at the CSIC, we are working every year to implement and promote measures that support true gender equality both at the institute and the field of AI in general. With more than 80 people, including researchers, students, technical and administrative staff, women at the institute constitute 31% of the total personnel.

Despite being a standard number in the technological research field, we are continuously working on increasing women's presence at our institute, specifically amongst our scientific staff.

In addition to gender diversity, we also want the IIIA to be a meeting point for all people regardless of origin, contributing to AI research and enriching the cultural diversity of the IIIA family. Currently, people from more than twelve countries belong to our team.

# People come first

We firmly believe that in any human activity, people and their wellbeing come first. During these 25 years, many researchers, administrators, students, technicians, and other personnel have passed through IIIA. With all, we have strived to achieve a relaxed yet productive work environment. Social activities have been our way to unite us and give us a sense of community. End-of-year concerts, luncheons in the Catalan countryside, and celebrations of academic success are our signature.

Photographs of the IIIA family at work and social events that we usually organise in the middle of nature a couple of times a year. IIIA researchers in 2011, 2018 and 2017. Family field trips in 2003 and 2009.


**End-of-year concert: Üsküdar'a gider iken (anonym) Gülnihal (Dede Efendi, 1778-1846)**

Performers
- Jordi Sabater-Mir
- Oguz Mulayim
- Marco Schorlemmer
- Àngel Cerdanya
- Eva Armengol
- Josep Puyol

# Science at the IIIA

### Autonomous Agents and Multiagent Systems

This research theme addresses the theory and implementation of computational systems composed of several interacting intelligent agents. These systems are necessary when problems are difficult or impossible to solve with a monolithic system, and tasks need to be distributed over several autonomous computational entities. At IIIA, we carry out scientific research of excellence in areas that are central to this field, such as computational models of negotiation, control and organisation, trust and reputation, optimisation, semantics, and recommender systems, with applications to e-commerce, transportation, logistics, education, digital humanities, and mutual-support communities.

### Logic and Reasoning

Logic and reasoning models for Artificial Intelligence, based on systems of classical or non-classical propositional and first-order logics, are the main tools to simulate human-reasoning. It defines the research area of Knowledge Representation and Reasoning (KRR) that provide foundations, results and solid methodologies that lay at the ground of symbolic AI. At IIIA, we develop logical systems and automated reasoning tools to represent and reason with incomplete information. We provide the area with several elaborated models for approximate, non-monotonic, causal, many-valued, fuzzy, uncertain or probabilistic reasoning—both from the theoretical and application perspectives.

### Machine Learning

The research on Machine Learning at IIIA focuses on developing ML algorithms, models, software and applications. From an algorithmic/modelling perspective, the group pursues research in Probabilistic Graphical Models, Case-Base Reasoning, Transfer Learning, and Deep Learning. From the software and applications perspective, the group concentrates on the application areas such as Social Networks, Music, Robotics, Multiagent Systems, Bioinformatics, and Healthcare.

### Norms and Normative Systems

Norms are the rules that govern behaviour in groups and societies. They motivate and influence individual actions by dictating what behaviour is deemed appropriate or not. Social norms have been extensively studied by anthropologists, sociologists, philosophers, and economists in the hope of understanding how norms emerge in societies, motivate individual action, influence market behaviour, ... In multiagent systems, norms and normative systems gained tremendous attention due to their success in coordinating agent behaviour. IIIA has a long history in this field, with research focus varying from norm formalisation and norm implementation and operationalisation, to norm selection, norm synthesis and the use of norms as means to value-alignment.

### Case-Based Reasoning

Case-Based Reasoning (CBR) systems can solve new problems using domain knowledge and the experience acquired in solving precedent problems. The two basic mechanisms used in CBR are (i) the retrieval of solved problems (cases) using some similarity criteria and (ii) the adaptation of the solutions applied in the precedents to the new problem. Case-based reasoning techniques are appropriate for problems where we can obtain many examples of solved problems. CBR is a powerful methodology that allows incremental prototyping and short design cycles. IIIA is an international referent on CBR with high impact contributions both in research and in applications.

### Trust and Reputation

The field of computational trust and reputation models deals with the design and development of computational models that provide an artificial entity (or computer software) with the capability to evaluate other entities' trust and reputation so they can act accordingly. IIIA is an international referent in this field. Researchers at IIIA have participated in several national and international projects and generated highly cited papers on this topic. The technologies developed at IIIA are recognized at a global level.

# Science at the IIIA

AI is a vast multidisciplinary scientific subject, including the foundations of mathematical logic, machine learning, agents, robotics, knowledge representation, among many others. Besides, it is applied to almost any imaginable domain of interest like industry, health, energy, education, social behaviour, or archaeology, to name a few. Here we outline some of the areas where IIIA plays a relevant role in the international scientific community.

### Satisfiability Problem (SAT)

Satisfiability Testing (SAT) is a logic-based approach to solving combinatorial problems. It is highly competitive because it uses powerful inference techniques, and there exist fast SAT solvers with good scaling properties. Moreover, this area of research considers richer SAT-based formalisms as Satisfiability Modulo Theories (SMT), Maximum Satisfiability (MaxSAT) and Minimum Satisfiability (MinSAT). Such formalisms allow solving optimisation problems too. Bioinformatics, planing and hardware verification routinely use SAT. IIIA has more than twenty years of experience in this field. We have developed solvers for SAT, MaxSAT and MinSAT that won several international competitions. IIIA has also studied the structure of industrial SAT instances, solved academic and real-world problems, analysed the complexity of several satisfiability problems, and defined inference systems for MaxSAT and MinSAT.

### Team Formation

Nowadays, the composition and formation of effective teams are essential for both companies to assure their competitiveness and for a wide range of emerging applications exploiting collaboration. Team formation research is of interest to many fields of science, from organisational psychology to computer science. In particular, many real-world problems require allocating teams of individuals to tasks. For instance, forming robot teams for search and rescue missions, including groups of unmanned aerial vehicles for surveillance, or grouping students to undertake school projects. IIIA is leading research in the design of novel algorithms at the convergence of organisational psychology and computer science, facilitating the formation of teams of students and their allocation to industrial internships. Edu2Com, is at the heart of the AI4Citizen pilot of the AI4EU project. Thus, education authorities count now on a software tool for automating this time-consuming, manual process.

# Science at the IIIA


The 1505 edition of Arbre de ciència by Ramon Llull (1232 -1316), printed in Barcelona. *SC.L9695.482ab, Houghton Library, Harvard University. Ramon Llull was a precursor of Artificial Intelligence. Our cluster's name, Ars Magna, is in homage to one of his most important works.

### Organisations and Institutions

A key task in multiagent systems is to support the coordination of several autonomous agents into performing a collective task. To address this task, we (at IIIA) have produced seminal work on electronic institutions, which involved a paradigm change in the governance of online social interactions and has influenced subsequent work in organisational and normative approaches in MAS. IIIA continues these developments along different fundamental lines like collaborative problem solving and the imbuement of values in collective interactions. The coordination frameworks developed at IIIA have been applied in a wide variety of problems like online auctions, collaborative learning environments and value-driven policy design.

### Social Coordination, Collective Intelligence

The term collective intelligence refers to shared or group intelligence that emerges from the collaboration, respectively the collective effort, of many individuals. The expertise of the IIIA in this context is focused particularly on a subfield known as swarm intelligence, in which the goal is to design intelligent multi-agent systems by taking inspiration from the collective behaviour of animal societies such as ant colonies, flocks of birds, or fish schools. In other words, social coordination and interactions between individuals serve as the source for the development of intelligent systems, for example, for optimization. The IIIA is a reference in this field, especially for the work on a technique known as ant colony optimization.

### Inductive Learning

The goal of Inductive Learning is to construct models useful mainly for predictive tasks. However, inductive models also allow extracting regularities or patterns that make visible similarities and differences among an application domain's classes. Such patterns provide an excellent tool for experts to understand better both the model's prediction and the whole domain. At IIIA, we have used Inductive Learning methods to analyze similarities and differences among benign and malign moles (melanomas), characterize highly productive cows of dairy farms, and analyze electoral results.

### Optimisation & Combinatorial Problems

Optimisation applications are ubiquitous in modern society and arise in networking, manufacturing, transportation, distribution, reservation systems, and emergency response systems, to name a few. Furthermore, optimisation is a core, transversal technique for Artificial Intelligence since many AI problems require solving some optimisation problem. Solving an optimisation problem boils down to finding the best available values of some objective function given a defined domain. IIIA specialises in combinatorial optimisation, a particular sub-field of optimisation concerned with computing the best solution in a usually huge space of discrete alternatives. Along this line, IIIA has developed novel algorithms and theoretical results for forming coalitions of individuals. This work has been applied to transportation scenarios to assemble shared rides between citizens in smart cities and share loads between logistics companies.

### Automated Negotiations

Automated negotiation deals with autonomous agents that are purely self-interested but need to cooperate to ensure beneficial outcomes. Negotiating agents propose potential solutions to each other and accept or reject the others' proposals. The challenge is to find the right balance between maximizing the agent's own utility and maximizing the likelihood of the proposal being accepted by the other agents. The IIIA is at the forefront of this research topic, especially when applying automated negotiations to highly complex scenarios that require intelligent search algorithms to explore the space of potential proposals.

### Natural Language Processing

Natural Language Processing (NLP) studies computational methods to read, understand and make sense of the human languages, to be used in applications such as information extraction from large amounts of natural language data, dialogue systems and machine translation. At IIIA, we conduct research on machine learning approaches to NLP, specifically in learning unsupervised language representations for the syntactic-semantic analysis of language, targeting top-tier conferences of the Association for Computational Linguistics. In addition to fundamental research, we also develop NLP systems with cutting-edge methods and push technology transfer to nurture the industry around natural language processing systems.

### Probabilistic Graphical Models

Probabilistic graphical models (PGMs) provide a mathematically well-founded approach for dealing with uncertainty. Furthermore, probabilistic models are interpretable and can be integrated with available domain knowledge coming from experts as well as with available data. As argued by Goodfellow et al., "structured probabilistic models are a key ingredient of many of the most important research topics in deep learning." At IIIA, we are actively researching approximate inference in PGMs, stochastic optimization in PGMs,  and the use of PGMs for crowdsourcing and citizen science, founded by the EU projects Crowd4SDG and HumaneAI-net.

# Science at the IIIA

### Responsible AI

Research work developed recently under the banner of ethics in AI range from philosophical investigations on the moral agency of autonomous entities and legal issues related to their autonomy and accountability, to ethical concerns with regards to the behaviour that more powerful technologies enable, raising the voice for explainable, trustworthy, transparent, and beneficial AI. IIIA has an active research team, with a number of ongoing European funded projects, dedicated to the topic Responsible AI. The focus is on the technical realisation of ethically-compliant AI systems, where we address issues like value engineering and value alignment of AI systems.

### Recommender Systems

Recommender Systems' area is devoted to providing mechanisms that can recommend an item (object, action, content, etc.) to a user given particular necessities and a specific context. Recommender Systems use different AI techniques that exploit various sources of information like the user's characteristics, historical data, or similarities among the recommended items. The IIIA has developed proprietary technology that extends the traditional capabilities of this kind of systems. At IIIA, we have a long experience in designing this kind of techniques and applying them to diverse domains like supermarkets, tourism, and education.

### Metaheuristics

Metaheuristics are algorithms for solving hard optimisation problems arising mainly in the industrial sector, but also in the educational, social, or medical context. Example applications include vehicle routing, loading and packing, bioinformatics, as well as rostering and timetabling. The family of metaheuristics includes well-known techniques such as evolutionary algorithms and tabu search. At the IIIA, we do research along three lines: (1) developing new metaheuristic techniques, (2) improving existing techniques, and (3) applying metaheuristics to real-world problems. The challenge is to adapt the general algorithmic idea to the specific problem at hand. The IIIA is at the forefront of this research topic, especially for the hybridisation of metaheuristics with other optimisation techniques.

### Concept Systems and Ontologies

Concept systems consist of representations of human concepts and their relations, typically organised taxonomically using formal ontologies. They are important for defining and organising the knowledge and terminology of a particular domain, thus fostering semantic interoperability and knowledge sharing. At IIIA, we study the cognitive, mathematical and computational foundations of concept systems and have developed mathematical theories and computational techniques for concept invention and semantic alignment. We have also explored the application of computational concept systems and ontologies to a wide range of domains such as architecture and construction, green innovation, recommender systems and computational creativity.

The Agreement Technologies team members at a project meeting at the Monestir de Poblet in 2011. Agreement Technologies was a CONSOLIDER project developed between 2007 and 2014. About one hundred researchers were involved.

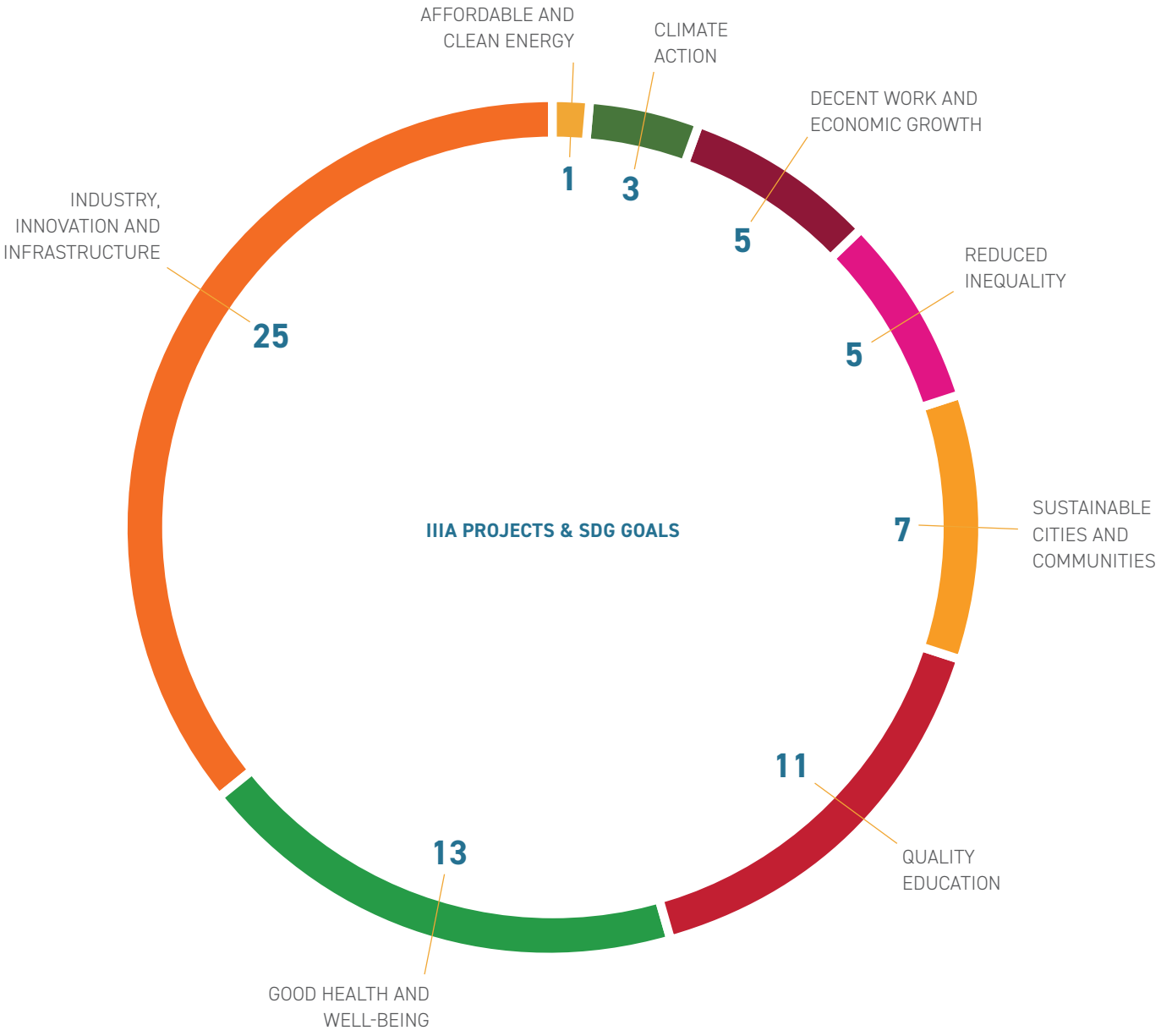
### Reinforcement Learning and Case-Based Reasoning for Transfer learning

This research addresses one of the most important aspects of Machine Learning, specifically the problem of Transfer Learning in the context of humanoid robotics. The goal is to transfer previously learned skills in a specific task to perform another different, although related task. One of the results achieved is the following: once a robot has learned, using reinforcement learning, to keep a double inverted pendulum in balance, it transfers what has been learned, to speed up the process of learning to walk robustly. The proposed algorithm combines reinforcement learning with case-based learning and reasoning. Transfer learning is essential to move towards the achievement of increasingly general artificial intelligences, undoubtedly the most ambitious goal of AI.

### Mathematical Fuzzy Logic

Mathematical Fuzzy Logic (MFL) is a sub-discipline of Mathematical Logic that studies logical formalisms in which formulas are evaluated in the real unit interval [0,1], rather than the classical truth-values set {0,1}. MFL aims at formalizing a notion of gradual truth that underlies Zadeh's Fuzzy Sets theory. At IIIA, we study logical systems related to MFL from the logical and algebraic perspectives, deepening the relationship between MFL and theories of uncertainty like possibility and probability theories and their application to similarity and preference-based reasoning models. IIIA researchers coordinate the international working group of the European Society for Fuzzy Logic and Technology (EUSFLAT) on that subject.

# Sustainable development at IIIA




### Smart Cities

IIIA helps fulfill the SDG on making cities and human settlements inclusive, safe, resilient and sustainable. We contribute valuable fundamental research in alternative low-carbon transport systems such as ridesharing. Additionally we do research in opinion mining, which has led to effective transfer of technology to Citibeats. IIIA helps Citibeats develop a machine learning-based platform to assist public administrations in gathering citizens' opinions and concerns using intelligent social network sensors. Furthermore, as part of the Crowd4SDG project, IIIA has put forward decidim4CS, a platform to ease the inclusive and democratic management of citizen science projects.

### Industry

Industry 4.0 refers to a new goal in the industrial revolution, mainly focused on interconnectivity, automation, machine learning, and real-time data. AI is a central element of this transformation, closely related to the growing accumulation of large amounts of data, algorithms to process it, and the massive interconnection and coordination of intelligent digital systems and devices. IIIA has contributed to the transference of technology designing Decision Support Systems based on novel Optimization Algorithms and Machine Learning techniques that provide transparent information and allow operators to make informed decisions for a sustainable and inclusive industry.

### Education

AI, in its origins, have been applied to education, in particular to personalised education. Adapting the contents to each student is a pedagogical imperative that is difficult for teachers to achieve when the groups are large or when the economic resources dedicated to education are limited. Several research groups developed simple systems of personalised education in the 1960s. Today, these systems have reached a remarkable level of sophistication, and Artificial Intelligence will become a fundamental tool for education soon. We have contributed with theoretical results on team formation algorithms applied to support task-oriented learning activities at our institute. At IIIA, we have also engineered tools to edit and execute lesson plans and proposed algorithms for student peer-assessment.

### Healthcare

The current trend of moving towards a more Predictive, Preventive, Personalized, and Participatory medicine, known as 4P Medicine, is changing the healthcare paradigm. Digital technologies are playing an important role in this 4P paradigm generating a volume and variety of information never seen before. Artificial Intelligence is contributing by providing tools for the management and exploitation of this huge amount of data. IIIA is focused on the design of novel algorithms to provide solutions able to incorporate advanced Descriptive, Diagnostic, Predictive, and Prescriptive capabilities to Clinical Decision Support Systems (CDSS).

# Scientific Leadership

**The six IIIA EurAI fellows**

- Ramon López de Mántaras
- Carles Sierra
- Enric Plaza
- Pedro Meseguer
- Juan Antonio Rodriguez
- Lluís Godo

### EurAI

EurAI is the European Association for Artificial Intelligence founded in 1982 as a representative body for the European Artificial Intelligence community. Its aim to promote the study, research and application of Artificial Intelligence in Europe. Currently, IIIA has six EurAI fellows, and Carles Sierra, IIIA's director, has been elected EurAI's president in 2020.

### ACIA

ACIA is the Catalan Association for Artificial Intelligence. It is a non-profit association for the advancement of AI in Catalan society. Its main goal is to support the communication between people and organisations involved in AI and promote social, cultural, scientific, economic and governmental awareness.

ACIA is a member of EurAI, and Josep Puyol-Gruart, a researcher at IIIA, been the ACIA president since 2016.

### IEC

The Institut d'Estudis Catalans (IEC) is a centre for Catalan studies and aims at promoting and developing research in different fields of science and technology with focus on Catalan culture. As such, the institute is known to have a strong influence on society. The IEC is structured in sections, each consisting of a maximum of twenty-eight full members. Professor Ramon López de Mántaras has been a full member of the Science and Technology Section since 2016.

CSIC Researchers attending AIHub's first meeting at IIIA in November 2019.

### AI HuB

In recent years, there has been a growing interest, at the academic, political, and industrial level, in AI research and development. Governments and companies are dedicating significant investments in AI, and focus is directed to the definition of AI regional strategies for the next decade. Different autonomous communities and the Spanish government have been working on defining these strategies, mapping competencies, and establishing a dialogue with the main actors in the scientific and technological ecosystem.

Artificial intelligence is considered one of CSIC's main strategic themes for the next decade. Areas such as robotics, machine learning, data science, knowledge representation, multi-agent systems, intelligent control, ethical, legal and socio-economic aspects of AI, amongst others, are active lines of research for various CSIC research groups. An AI network is being formed to coordinate all these AI-related activities. Several activities will be supported by the CSIC, including scientific exchanges, summer schools, preparation of educational materials, and thematic workshops, among many others.

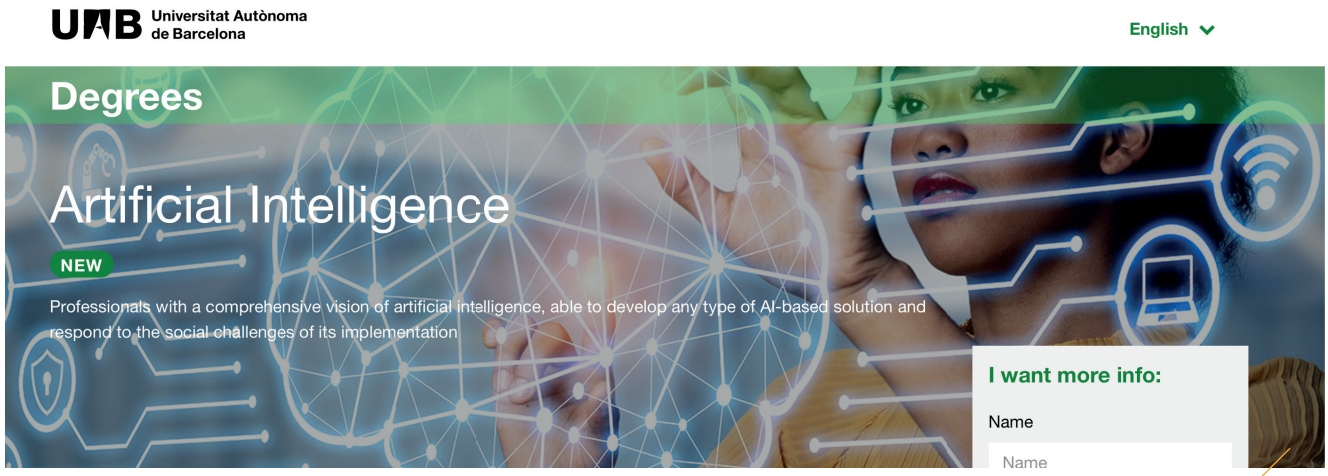
> IIIA researchers hold influential positions in prominent organisations and initiatives.

### CSIC's White paper on AI

In July 2019, CSIC's Presidency identified 12 strategic thematic areas to develop during the next decade (2021-30). One of them was Artificial Intelligence, Robotics and Data Science. In 2020, IIIA co-ordinated the writing of a white paper on AI in collaboration with 32 other research groups and over 200 researchers.

### The Spanish Government's Artificial Intelligence Advisory Council

In 2020, the Spanish government's has set-up the Artificial Intelligence Advisory Council to provide independent advice and recommendations on the measures to be taken to ensure AI's safe and ethical use. Internationally renowned Spanish experts in AI will contribute to the National Artificial Intelligence Strategy's completion and implementation. One of these experts is Carles Sierra, current director of IIIA.




**New AI degree at the UAB**

The Universitat Autònoma de Barcelona (UAB) is starting a new academic programme on Artificial Intelligence for the academic year 2021/22.

Catalonia's Government, under the CATALONIA.IA strategic framework, is supporting the degree that aims to cover the need for artificial intelligence experts in Europe. It involves several of UAB's teaching and research centres, such as the Computer Vision Centre (CVC) and the Artificial Intelligence Research Institute (IIIA-CSIC).


IIIA has organized the International Joint Conference on Artificial Intelligence (IJCAI) in 2011. 1500 researchers visited Barcelona to present their work.

# IIIA researchers' involvement in top AI journals

## Editors in Chief

**Fuzzy Sets and Systems**
- Lluís Godo
  - since 2016

**Journal of Autonomous Agents and Multiagent Systems**
- Carles Sierra
  - 2014-2019

**Computación y Sistemas, Revista Iberoamericana de Computación**
- Ramon López de Mántaras
  - 1997-2002

**Artificial Intelligence Communications**
- Ramon López de Mántaras
  - 1992-1996

## Associate Editors

**Artificial Intelligence Journal**
- Christian Blum
  - since 2020
- Felip Manyà
  - since 2020
- Juan Antonio Rodriguez
  - since 2016
- Lluís Godo
  - since 2014
- Ramon López de Mántaras
  - 2007-2014
- Carles Sierra
  - 2011-2016

**Autonomous Agents and Multi-Agent System**
- Lluís Godo
  - since 2015

**Computers & Operations Research**
- Christian Blum
  - since 2016

**Electronic Commerce Research and Applications**
- Juan Antonio Rodriguez
  - 2010-2017

**Engineering Applications of Artificial Intelligence**
- Christian Blum
  - since 2018
- Carles Sierra
  - 2010-2012

**Fuzzy Sets and Systems**
- Tommaso Flaminio
  - since 2017
- Lluís Godo
  - 1998-2016

**International Journal of Approximate Reasoning**
- Tommaso Flaminio
  - since 2018

**Journal of Artificial Intelligence Research**
- Juan Antonio Rodriguez
  - since 2017
- Carles Sierra
  - 2011-2018

**Natural Computing**
- Christian Blum
  - 2010-2017

**Neural Computing and Applications**
- Christian Blum
  - since 2012

**Pattern Recognition Letters**
- Ramon López de Mántaras
  - 1983-1998

**Soft Computing**
- Lluís Godo
  - 2012-2020

**Springer Series on "Emergence, complexity and computation"**
- Juan Antonio Rodriguez
  - since 2012

**Swarm Intelligence**
- Christian Blum
  - 2019-2020

**The Knowledge Engineering Review**
- Juan Antonio Rodriguez
  - since 2009

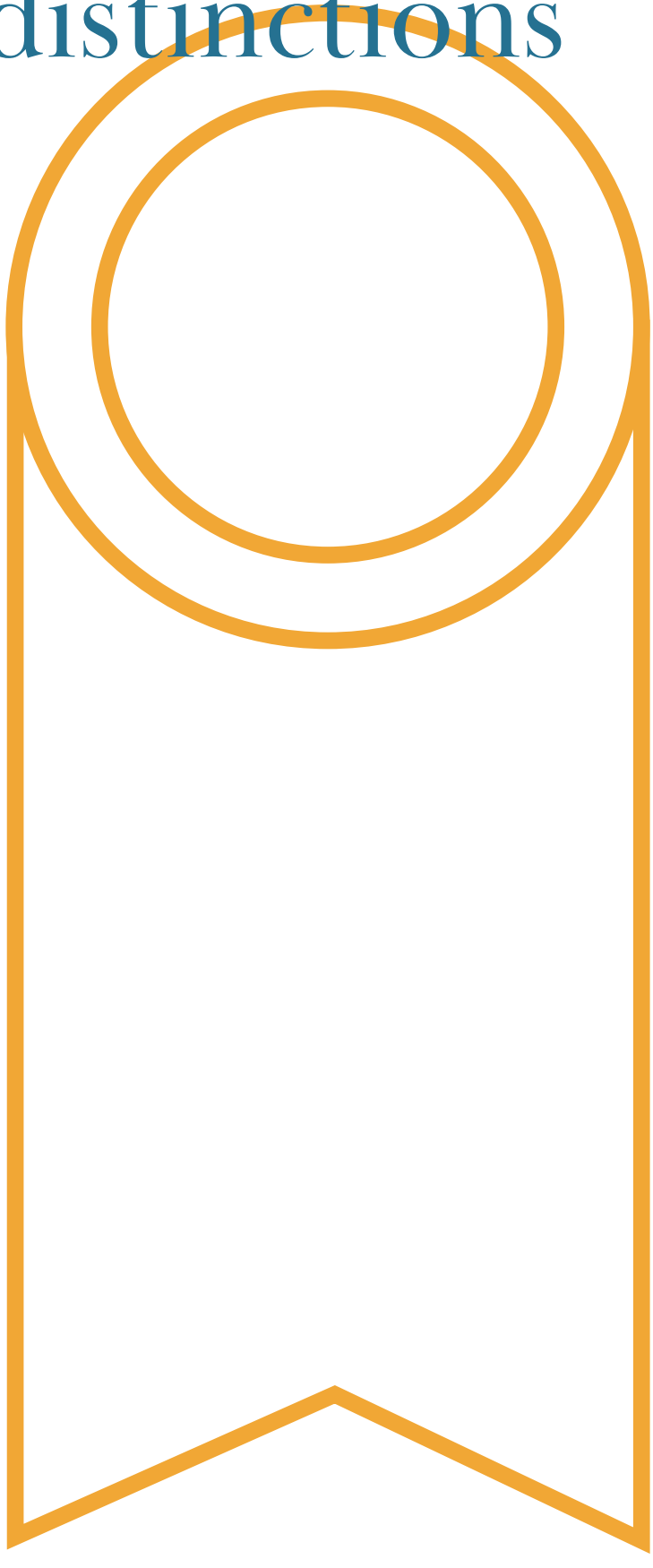
**Theoretical Computer Science**
- Christian Blum
  - since 2015

**Transactions of the Association of Computational Linguistics**
- Xavier Carreras
  - since 2017

**Human-Computer Studies**
- Carles Sierra
  - 2004-2018

**Web Intelligence and Agent Systems**
- Carles Sierra
  - 2010-2015

# Awards and distinctions



### 2011 Robert S. Engelmore Memorial Award

Professor Ramon López de Mántaras was honoured for his pioneering research contributions in a breadth of Artificial Intelligence areas, especially pattern recognition and case-based reasoning, leading to novel applications in design, diagnosis, and music, and for extensive international leadership and service for the AI community.

### Victor Lesser Distinguished Dissertation Award 2011 (IFAAMAS)

The PhD thesis entitled "Social Norms for Self-Policing Multi-Agent Systems and Virtual Societies" by Daniel Villatoro, and presented at the Universidad Autònoma de Barcelona, won the best PhD award. This thesis was supervised by Jordi Sabater.

### 2016 EurAI Distinguished Service Award

Professor Ramón López de Mántaras won the Distinguished Service Award 2016 of the European Association for Artificial Intelligence (EurAI) in recognition for his pioneering activities in AI in Spain since 1976, as well as for his service to the European AI community, including his work as former Editor-in-Chief of AI Communications and member of the Board of EurAI, and as Conference Chair of ECAI 2004.

### 2017 Donald E. Walker Distinguished Service Award

Professor Ramon López de Mántaras received the Donald E. Walker Distinguished Service Award at the opening ceremony of IJCAI-17 on August 22 in Melbourne. He is recognized for his substantial contributions and his extensive service to the field of Artificial Intelligence throughout his career.

### Best PhD on Multi-criteria Decision-making 2019 (Spanish Society on Statistics and Operations Research)

The PhD thesis entitled "Data-driven decision-making and its application to the corporate cash management problem" by Francisco Salas Molina, and presented at the Universitat Politècnica de València, won the best PhD award. This thesis was supervised by Juan Antonio Rodriguez.

### 2018 'Julio Rey Pastor' Award for Mathematics and Information and Communication Technologies

Professor Ramón López de Mántaras won this price for his pioneering research in many Artificial Intelligence areas, especially in pattern recognition and case-based reasoning, leading to novel applications in design, diagnostics and music, and for his broad international leadership and service to the AI community. According to the jury, "he has created a school in Spain in the field of Artificial Intelligence that has placed our country on the international map of this sector".

### 2019 ACM/SIGAI Autonomous Agents Research Award

Professor Carles Sierra was the recipient of the 2019 award by the selection committee for the ACM/SIGAI Autonomous Agents Research Award. He has made seminal contributions to research on negotiation and argumentation, computational trust and reputation, and artificial social systems. His work has pursued answers to fundamental agent research questions: how to interact and with whom, and how to design frameworks for agent interaction. This work played a significant role in establishing the foundations for these questions and motivating further research across the community. Prof. Sierra has also served the autonomous agents research community in various roles, including General Chair of the AAMAS conference, its Program Chair and Editor in Chief of the JAAMAS journal.

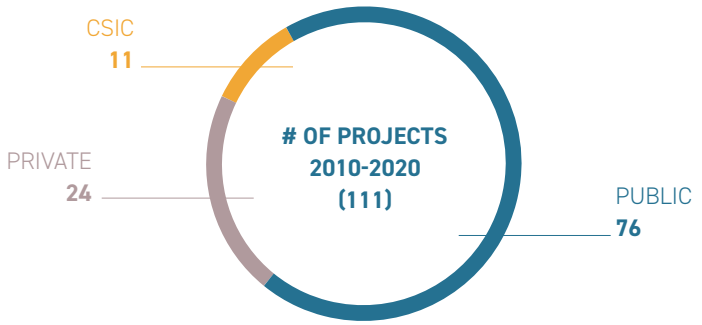
### Best PhDs awarded by the European Society for Fuzzy Logic and Technology

Marco Cerami won the EUSFLAT 2012 Best PhD Award for his PhD "Fuzzy description logics from a mathematical fuzzy logic point of view", supervised by Francesc Esteva and Lluís Godo. Amanda Vidal won the EUSFLAT 2015 Best PhD Award for her PhD "On modal expansions of t-norm based logics with rational constants", supervised by Félix Bou, Francesc Esteva and Lluís Godo.

### Other prices and distinctions

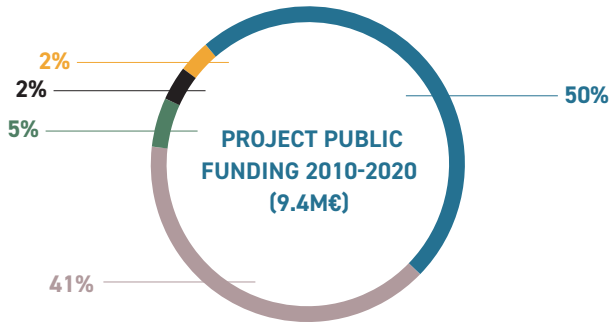
- ANTS 2020, Twelfth International Conference on Swarm Intelligence: Best Paper Award to "A New Approach for Making Use of Negative Learning in Ant Colony Optimization" by Christian Blum and Teddy Nurcahyadi.
- CCIA-2018, 21st International Conference of the Catalan Association for Artificial Intelligence: Best Paper Award to "Clause Branching in Max-SAT and MinSAT" by Josep Argelich, Chu Min Li, Felip Manyà and Joan Ramon Soler.
- CCIA-2016, 19th International Conference of the Catalan Association for Artificial Intelligence : Best Paper Award to "A Clause Tableau Calculus for MinSAT" by Chu-Min Li, Felip Manyà and Joan Ramon Soler.
- ICCC 2015, International Conference on Computational Creativity: Best Paper Award to "Generalize and Blend: Concept Blending Based on Generalization, Analogy, and Amalgams" by Tarek R. Besold and Enric Plaza.
- AAMAS 2009, International Joint Conference on Autonomous Agents and Multiagent Systems: Best Student Software Award to "HIHEREI: Human Interaction within Hybrid Environments Regulated through Electronic Institutions" by Isaac Pinyol, Dani Villatoro, Ismel Brito and Jordi Sabater.
- 2003 Agentcities International Agent Technology Competition: Best Agent Application to "IBUNDLER, an agent-based decision support for actual-world procurement scenarios" by Juan Antonio Rodriguez, Andrea Giovanucci, Antonio Reyes-Moro, Francesc Xavier Noria and Jesus Cerquides.

# Project funding 2010-2020





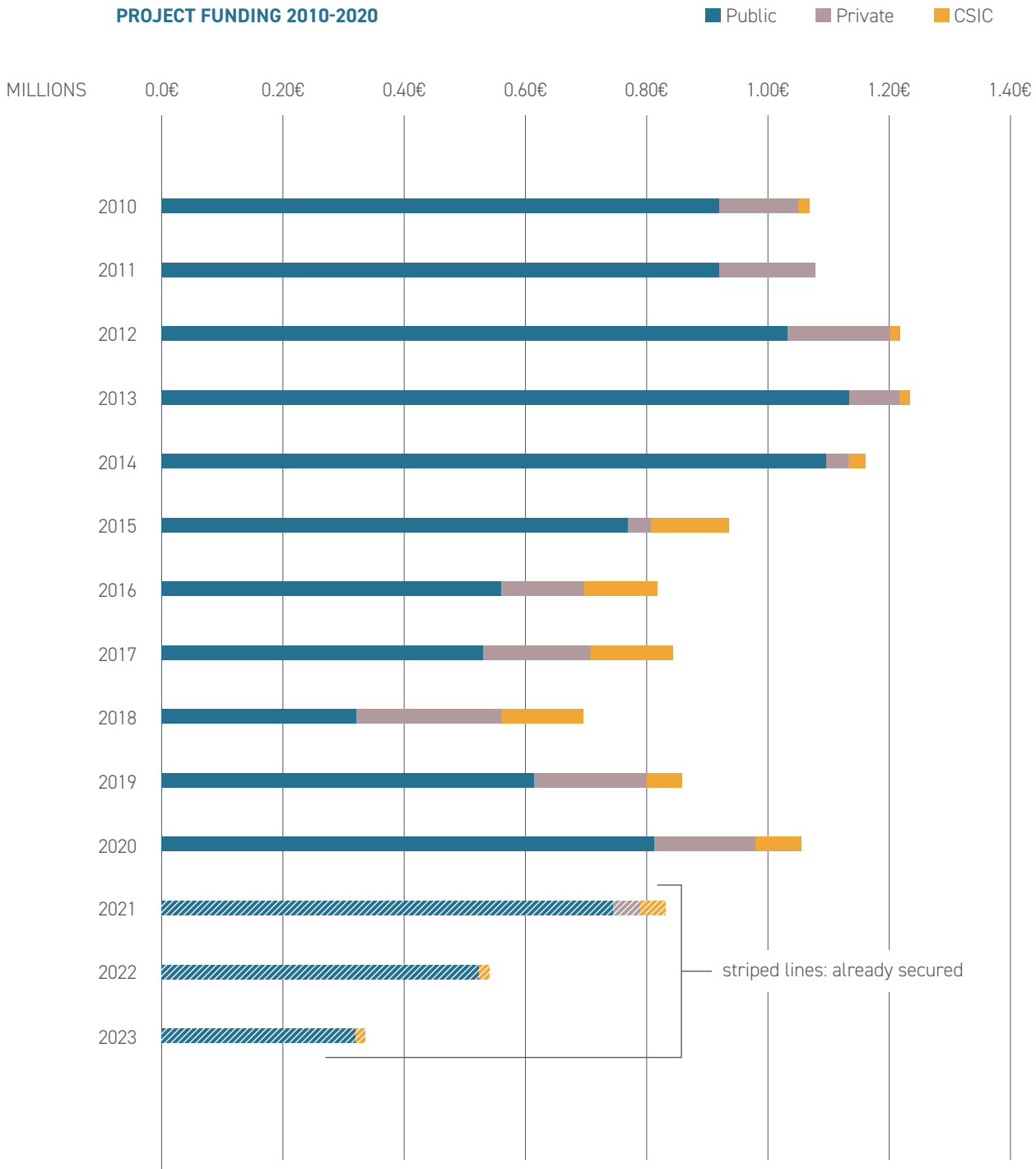
We have carried out 111 projects during the last decade with an overall budget of around 11 million euros. Most have been publicly funded. Those that are privately funded represent 14% of the total. We hope that this tendency of increased private funds, noted in the last few years, will be consolidated in the future.




The total public funding in the last decade has reached around 9.4 million euros. It is important to note that more than 40% of these correspond to European funding.

Spain Europe Catalonia International (nonEU) CSIC

## PROJECT FUNDING 2010-2020




In the last several years, IIIA's project budget have been fluctuating due to socioeconomic conditions. The ability to obtain external funding is is on average around one million euros per year. Note that when public resources decrease, private funding focusing on knowledge and technology transfer usually compensates. It seems that with the end of the last decade we are witnessing a recovery in public funding while private funding is kept at the same level. Currently consolidated projects are securing funds for the years 2021-2023 (see striped lines). These funds are mostly public, while we note that private projects usually are of short duration.

# Projects

# starting

# 2020

# SuMoL
# Substructural Modal Logistics For Knowledge Representation

The project "Substructural Modal Logics for Knowledge Representation" (SuMoL) is a bilateral I-LINK project funded by the Spanish National Research Council (CSIC). It involves the Artificial Intelligence Research Institute of the Spanish National Research Council from Barcelona (IIIA-CSIC) and the Institute of Computer Science of the Czech Academy of Science from Prague (ICS-CAS).

The SuMoL project aims at fostering the collaboration between the two IIIA-CSIC and the ICS-CAS by financing 22 research visiting periods (12 of the IIIA-CSIC team to Prague and 10 of the ICS-CAS team to Barcelona) and two workshops (one in Prague and one in Barcelona) to be organized in the two years 2020-2022.

The scientific aspects of this project aim at putting forward a systematic study of substructural modal logics, understood as those modal logics in which the modal operators are based upon the more general ground of substructural logics.

**PI: Tommaso Flaminio**

CSIC
Consejo Superior de Investigaciones Científicas

# Do-calculus based and machine-learning-based causal analysis algorithms in healthcare-related settings

**PI: Jesús Cerquides**

Many studies in the health field are observational, empirical and non-experimental (no intervention by the researchers in the process of generating data), and the corpus of observational data grows high speed. Traditionally, algorithms used in this type of study have been algorithms statistics that work by searching for correlations in the data. Recently, algorithms based on machine learning, which also work by looking for correlations in data have gained popularity. These have meant an increase in predictive capacity and a shift in approach from observation to prediction. However, these approaches do not take into account explicitly a fundamental property of the process of data generation: causal relationships. These relationships can be of great interest to researchers since many studies try to answer questions primarily causal: "Has the implementation of the protocol of interest cause a change in the population of interest?" "How will a specific individual react to the application of the protocol, or how would and individual react if untreated?" "Do genes or eating habits this or that disease?". The approaches that obviate causal relationships constitute an epistemological limitation, and try to answer causal questions using the correlation as an approximation of causality is, to this day, a limiting strategy. This thesis' objectives are twofold: on the one hand, to compare and benchmark algorithms of causal analysis based on do-calculus and machine learning, focusing on efficiency and versatility. On the other hand, to develop a general-purpose algorithm (for healthcare) that uses a combination of the two types of algorithms mentioned above, under a series of assumptions and terms. This task will be carried out using specific open source programming languages and libraries, such as Python's do-why library. The output will be tested and validated in several datasets managed by AQuAS, and in the cohort GCAT, and will try to answer causal questions relevant to the health field.

Generalitat de Catalunya
Departament d'Empresa i Coneixement
**Secretaria d'Empresa i Competitivitat**

Agència de Qualitat
i Avaluació Sanitàries
de Catalunya

# DIAGRAFIS
# Diagrammatic Reasoning and its Formalisation with Image Schemas

Diagram-based languages and reasoning with them are important for STEM disciplines (Science, Technology, Engineering, Mathematics). The study of these languages has been carried out mainly from the perspective of their underlying formal logic. In recent decades, the importance of embodiment in human conceptualization and reasoning has become evident, giving rise to cognitive science theories that define cognition based on image schemes, metaphors, analogies and conceptual integrations. With this project, we will explore a new line of research on diagrammatic reasoning and its formalization with image schemas and conceptual metaphors, extending and complementing the previous and current research of the research team.

The objectives are:

- to model and formalize diagrammatic languages through metaphors and conceptual integrations based on image schemes
- to implement diagrammatic reasoning in computer systems based on their modelling as metaphorical inferences
- to explore the application of the model, the formalization and the implementation in computer systems to support STEM disciplines
- to define future international research initiatives based on the results

**PI: Marco Schorlemmer**

CSIC
Consejo Superior de Investigaciones Científicas

HUMANE AI NET

# HumanE-AI Net
# HumanE AINetwork

The HumanE AI Net brings together top European research centres, universities and key industrial champions into a network of excellence centres beyond a narrow definition of AI. It combines world-leading AI competence with key players in related areas such as HCI, cognitive science, social sciences and complexity science. This is crucial to develop a truly Human Centric brand of European AI. We will leverage the synergies between the involved centres of excellence to develop the scientific foundations and technological breakthroughs needed to shape the AI revolution in a beneficial direction to humans both individually and societally, and adhere to European ethical values and social, cultural, legal, and political norms. The core challenge is developing robust, trustworthy AI capable of "understanding" humans, adapting to complex real-world environments, and appropriately interacting in complex social settings. The aim is to facilitate AI systems that enhance human capabilities and empower individuals and society as a whole while respecting human autonomy and self-determination. The HumanE AI Net project will engender the mobilization of a research landscape far beyond direct project funding, involve and engage European industry, reach out to relevant social stakeholders, and create a unique innovation ecosystem that provides a many-fold return on investment for the European economy and society. We will make the results of the research available to the European AI community through the AI4EU platform and a Virtual Laboratory, develop a series of summer schools, tutorials and MOOCs to spread the knowledge, develop a dedicated innovation ecosystem for transforming research and innovation into an economic impact and value for society, establish an industrial PhD program and involve key industrial players from sectors crucial to the European economy in research agenda definition and results from evaluation in relevant use cases.

**PI: Jesús Cerquides**

European Commission

# PULSE
# X-ray pulse detection using AI

Astrophysicists are interested in the observations of remote objects in the X-ray spectrum. But X rays are blocked by the upper atmosphere, and then it is necessary to use telescopes installed on artificial satellites.

ATHENA X-ray Observatory is a mission of the European Space Agency (ESA) science program (2014), to be launched in the early 2030s. ATHENE will contain X-IFU X-ray Integral Field Unit, that is, a cryogenic X-ray spectrometer, based on a large array of Transition Edge Sensors (TES): with a range of 0.2 – 12 keV, a spectral resolution of 2.5 eV, and a time resolution of 10μs; the field of view with 5" pixels, over 5 arc minutes (0.083 degrees) in equivalent diameter.

The Institute of Physics of Cantabria (IFCA) is participating in the Horizon 2020 (Integrating and opening research infrastructures of European interest) project AHEAD2020: Integrated Activities for the High Energy Astrophysics Domain. The task14.4, "Machine learning techniques for micro-calorimeter data-reduction" is coordinated by Maite Ceballos (IFCA). It includes a prospective analysis of the different machine learning techniques, applicable to the triggering and reconstruction of the X-IFU current pulses, aimed at improving S/N and energy resolution. These techniques' performance will be compared with already established traditional methods such as optimal filtering, using figures of merit like the energy resolution or the processing requirements.

IIIA collaborates in this task offering its knowledge and experience in Artificial Intelligence to deal with a noise signal containing X-ray pulses of different shapes and sometimes overlapping. We are working with synthetic and real signals, and we are designing algorithms to detect the pulses, separate them when overlapping, and measure the energy of each pulse. We are exploring machine learning techniques as mainly CNN and also SVM. We have to consider that it is not possible to send all the data to earth, implying that the detection and analysis have to be made onboard with minimal computational resources.

**PI: Josep Puyol-Gruart**


European Commission

IFCA
Instituto de Física de Cantabria

# MARA

# Development of advanced human-machine interaction mechanisms in the context of argumentative recommenders.

The project aims to study different mechanisms that allow advanced interaction between humans and a recommendation system with argumentative capacity. This project is the continuation of various projects in recent years at the IIIA, where we have developed a multi-recommender system with argumentative capacity. We have already applied this multi-recommender system in two different domains: shopping in large stores (SmartExFood project IPT-2012-0688-060000) and the generation of personalised trips (AS4OTA project Ref-20174622).

The project has two main objectives:

1 - Improve the existing multi-recommender system, precisely its argumentative capacity. We plan to expand the logical inference system that is currently used, allowing, on the one hand, to increase the complexity of the explanations and on the other to improve the possibilities of dialogue between the multi-recommender and the user.

2 - Study and design innovative mechanisms to communicate to the user the explanations generated by the multi-recommender. Here we want to explore forms of communication that are not limited to just a text on a screen. Specifically, we will explore the possibility of incorporating innovative technologies such as virtual reality and augmented reality and new forms of interaction based on intelligent interfaces.

**PI: Jordi Sabater-Mir**

CSIC
Consejo Superior de Investigaciones Científicas

# TECSAM the Innovation Network of New Technologies in Mental Health

The goal of the Innovation Network of New Technologies in Mental Health is to provide treatment to all people with mental health disorders and to improve the quality of life of persons with severe mental health disorders and their families through technological advances based on research results and the detection of needs that would signal areas with treatment gaps.
Specifically, TECSAM aims to bring together and integrate all mental health research carried out in the territory of Catalonia, optimising the resources allocated to the valorisation and transfer of knowledge.

**PI: Josep Lluís Arcos**

Generalitat de Catalunya
Departament d'Empresa i Coneixement
**Secretaria d'Empresa i Competitivitat**

Agència de Gestió d'Ajuts Universitaris i de Recerca
AGAUR

Unió Europea
Fons Europeu
de Desenvolupament Regional

# CI-SUSTAIN

# Advanced Computational Intelligence Techniques for Reaching Sustainable Development Goals

**PI: Christian Blum**
**Jesús Cerquides**

In 2015, all United Nations member states adopted the Agenda 2030 for sustainable development with the global objective of achieving peace and prosperity for all people on the planet. The agenda sets out 17 sustainable development goals (SDGs). These goals urge countries to take action to end poverty and other deprivations through strategies that improve health and education, reduce inequality, and stimulate economic growth, all without negatively impacting climate change and preserving our planet. After several years working on AI for the social good, we identified specific computational challenges in optimization and machine learning that arise in application areas related to Agenda 2030 objectives. Our goal is to address these challenges by advancing state of the art in algorithmic aspects. This will be necessary because the optimization problems that arise in these application areas are large-scale problems that often cannot be solved with nowadays available heuristics or exact approaches. In fact, we plan to advance the state of the art along the following three lines. First, to contribute to the adaptation of metaheuristics for the application to large-scale problems. Second, to advance the combination of heuristic techniques with algorithmic ideas from operations research. Thirdly, to contribute to the improvement of optimization algorithms by machine learning techniques. The objective of the project is to demonstrate that the computational advances achieved allow improvements with respect to the state of the art in application areas that are aligned with some of the SDGs of the UN Agenda 2030 for Sustainable Development. In particular, we will address the following areas: (1) Peer-to-peer ride-sharing (related to SDG 11: Sustainable Cities and Communities); (2) Team-building (related to SDG 4: Quality Education); (3) Increasing children's energy responsibility (related to SDG 4: Quality Education); (4) Smart health systems (related to SDG 3: Good Health).


GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

# CORPORIS

# Theory and Computation of Embodied Conceptualisation for Information Systems

CORPORIS contributes to the conceptual and theoretical foundations for a mathematical and computational model of embodied conceptualisation, driven by its potential deployment and application in cognitive musicology and musical creativity.

**PI: Marco Schorlemmer**

In particular:

We aim at developing a category-theoretical model of the image-schematic structure underlying human conceptualisation. For this, we will focus on a core selection of basic musical concepts for which the image-schematic structure has been previously studied, to guide our formalisation.

We aim at designing and implementing a computational realisation of our formal model. The implementation will be carried out in the functional programming paradigm as it is more suitable for a category-theoretic model. This should eventually lead to an experimental pre-prototype of a computational aid with which we can execute and validate particular metaphorical inferences, from the image-schematic structure to the conceptualisation domain, such as music theory.

We aim at validating the model and its computational realisation on a conceptualisation of a core selection of musical concepts and with respect to metaphorical inferences relevant to cognitive musicology and musical creativity.

In this project, we aim at addressing the issue of conceptual diversity not as a problem to be solved, but as a richness to be embraced and built upon. We expect our approach to capturing both cross-cultural diversity and image-schematic invariants, and we set out to show this with musical concepts.

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

# ISINC — Inference Systems for Inconsistent Information: logical foundations

**PI: Lluís Godo**
**Felip Manyà**

In this project the main goal is to advance the state-of-the-art in inconsistency-tolerant inference models in different scenarios: MaxSAT techniques in classical and many-valued logics, non-classical graded logics, argumentation frameworks, both in theoretical and practical aspects and in their application to the analysis of discussions in social networks. The main difficulty we want to tackle is the existence of inconsistency in knowledge bases, a common property in knowledge bases that comes from real applications, especially when the information is obtained as the aggregation of information coming from different sources.

On the one hand, we plan to use extensions of different non-classical logics, mainly based on fuzzy logics and modal fuzzy logics, for being able to extract useful information from such kind of knowledge bases and being able to manage both uncertain and inconsistent information. We will define models over these expanded logics and inference algorithms that can be used to extract useful information under these new logics. The algorithms studied will be either ad-hoc or based on SAT/MaxSAT reductions.

On the other hand, we also plan to consider an approach for working with inconsistent information based on extensions of argumentation models, incorporating both uncertain and inconsistent information again. We will define argumentation models and algorithms for them, trying to identify special cases that can be solved with efficient algorithms. We also plan to study approximate inference algorithms for these problems, based on machine learning methods.

As an application domain, we plan to test our models and algorithms on different problems related to the analysis of discussions and comment threads in different social networks, where the inconsistency is a very common property in these scenarios, but we may also encounter uncertain information, as not all the pieces of information we find in them are always believed to have the same strength.

The first subproject will mostly focus on the theoretical aspects of the project, and its main activity will be the definition of new logical formalisms and inference systems to deal with inconsistencies in different scenarios. Some of the theoretical problems we propose are motivated by our experience in the development of proof procedures and the resolution of challenging combinatorial optimization problems.

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

# PROOFS
# Practical Proof Systems Beyond Resolution

Combinatorial problems that arise naturally in many domains (scheduling and planning, software and hardware verification, knowledge compilation, probabilistic modelling, bioinformatics, energy systems, smart cities, social networks, computational sustainability, etc.) can be encoded as a satisfiability problem (SAT) or one of its variants (CSP, MaxSAT,...). This large family of computational problems has been intensively studied, both from a practical and theoretical perspective.

Regarding practice, in the last decade, there has been a tremendous success in solving industrial combinatorial problems through Constraint Programming techniques, such as Satisfiability (SAT) solvers. Proof systems lie at the heart of state-of-the-art SAT/CSP/MaxSAT solving. In particular, CDCL SAT solvers contain, implicitly, a resolution engine that, once a conflict is found, learns anew clause that represents the reason for the conflict. From a practical perspective, the main goal of this proposal is to build new SAT solvers based on proof systems that are more powerful than resolution. We hope that this can have a great impact in practice since, in turn, it could boost MaxSAT solvers and other successful approaches using SAT technology such as Satisfiability Modulo Theories. However, to make this step it is necessary to automatize a better understanding and exploitation of the structure of Real-World problems through the application of Machine Learning (ML) techniques, which is another of the main themes of our work. In particular, we will study how to combine Deep learning and Reinforcement learning ML techniques, complex networks analysis and more powerful proof systems, creating a yet unexplored synergy between Machine Learning and proof systems for Constraint Programming.

**PI: Jordi Levy**

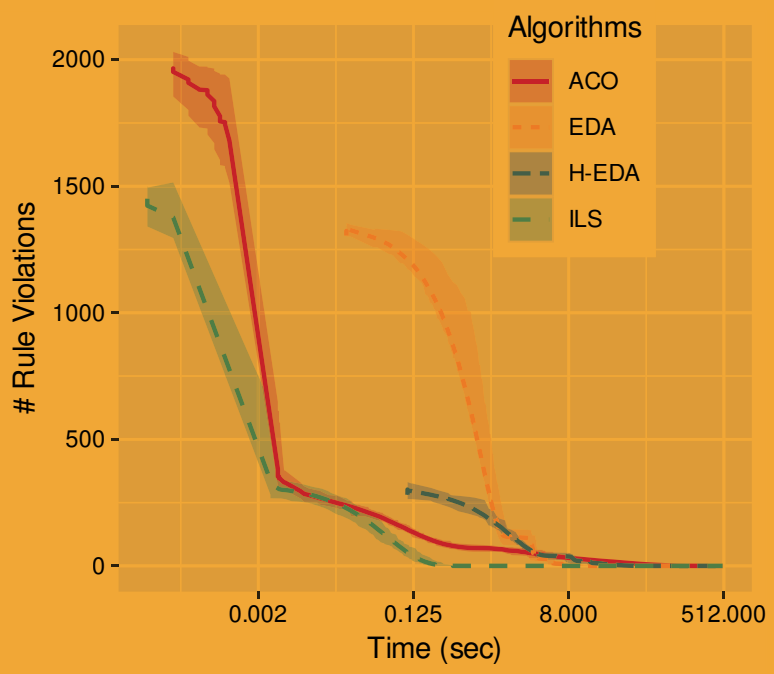
From a theoretical perspective, proof systems also play a major role. Indeed, several very powerful and general algorithmic principles based on solving (linear of semidefinite) relaxations of SAT (and more generally CSP instances), such as Lovasz-Schrijver, Sherali-Adams and the Lasserre hierarchies are naturally associated to proof systems. In several particular domains, it is not possible to go beyond these proof systems and, indeed, it is quite conceivable that many of the problems that are still resisting classification could be solved by some of them. However, the reach of these approaches is still not fully understood. Improving our understanding is the main theoretical goal of the proposal. On the one hand, we plan to extend the study of current proof systems to new CSPs, such as the family of Promise CSPs, recently introduced. Promise CSPs have received a lot of attention and constitute one of the most natural steps (after non-uniform CSPs were completely classified in 2017) to push further the so-called algebraic approach in the study of computational problems. Secondly, we plan to investigate new variants of existing proof systems towards the ultimate goal of expanding our toolkit of algorithmic approaches to be able to tackle many of the solvable CSPs of interest that still resist attack.

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

# SafetIA
# Artificial Intelligence for the Design of Safety-Critical Systems in Large Boolean Design Spaces

The project's main objective is to analyze whether the design of complex systems modelled based on (1) a set of safety requirements and (2) one or more performance objectives, can be automated using Artificial Intelligence techniques. The analysis is done in the context of safety-critical systems that have to comply with very strict safety standards (SIL1, ..., SIL4). The analysis considers, as an example, the design of railway interlocking systems. The analysis's objectives are to understand if the automation mentioned above is feasible, identifying the potential advantages and the limits.

**PI: Christian Blum**



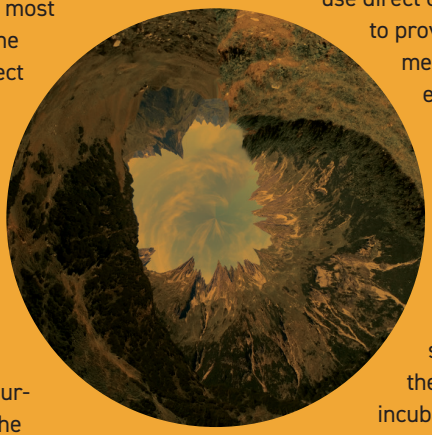

ikerlan
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Crowd4SDG

# Crowd4SDG Citizen Science for Monitoring Climate Impacts and Achieving Climate Resilience

**PI: Jesus Cerquides**

The 17 Sustainable Development Goals (SDGs), launched by the UN in 2015, are underpinned by 169 concrete targets and 232 measurable indicators. Some of these indicators have no established measurement methodology. For others, many countries do not have data collection capacity. Measuring progress towards the SDGs is thus a challenge for most national statistical offices. The goal of the Crowd4SDG project is to research the extent to which Citizen Science (SC) can provide an essential source of non-traditional data for tracking progress towards the SDGs and the ability of CS to generate social innovations that enable such progress. Based on shared expertise in crowdsourcing for disaster response, the transdisciplinary Crowd4SDG consortium of six partners will focus on SDG 13, climate action, to explore new ways of applying CS for monitoring the impacts of extreme climate events and strengthening resilience of communities to climate-related disasters. To achieve this goal, Crowd4SDG will initiate research on the applications of artificial intelligence and machine learning to enhance CS and explore the use of social media and other non-traditional data sources for more effective monitoring of SDGs by citizens. Crowd4SDG will use direct channels through consortium partner UNITAR to provide national statistical offices with recommendations on best practices for generating and exploiting CS data for tracking the SDGs. To this end, Crowd4SDG will rigorously assess the quality of the scientific knowledge and usefulness of practical innovations occurring when teams develop new CS projects focusing on climate action through three annual challenge-based innovation events, both online and in person. A wide range of stakeholders, from the UN, governments, the private sector, NGOs, academia, innovation incubators and maker spaces will be actively involved in advising the project and exploiting the scientific knowledge and technical innovations that it generates.



European Commission

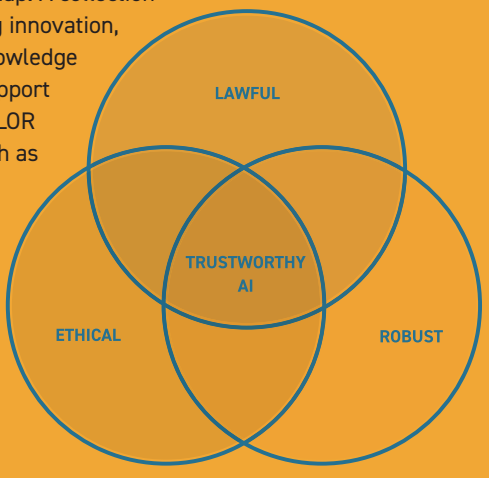
TAILOR

# TAILOR
# Foundations of Trustworthy AI - Integrating Reasoning, Learning and Optimization

**PI: Carles Sierra**

Artificial Intelligence (AI) and all the key digital technologies subsumed by the term AI today are an essential part of the answers to many of the daunting challenges we face. AI will impact the everyday lives of citizens as well as all business sectors. To maximize the opportunities and minimize the risks, Europe focuses on human-centered Trustworthy AI and is taking important steps towards becoming the worldwide centre for Trustworthy AI. Trustworthiness however still requires significant basic research, and it is clear that the only way to achieve this is through the integration of learning, optimization and reasoning, as neither approach will be sufficient on its own.

The purpose of TAILOR is to build a strong academic-public-industrial research network with the capacity of providing the scientific basis for Trustworthy AI leveraging and combining learning, optimization and reasoning for realizing AI systems that incorporate the safeguards that make them reliable, safe, transparent and respectful of human agency and expectations. Not only the mechanisms to maximize benefits, but also those for minimizing harm. The network will be based on a number of innovative state-of-the-art mechanisms. A multi-stakeholder strategic research and innovation research roadmap coordinates and guides the research in the five basic research programs. Each program is forming virtual research environments with many of the best AI researchers in Europe, addressing the major scientific challenges identified in the roadmap. A collection of mechanisms supporting innovation, commercialization and knowledge transfer to industry. To support network collaboration TAILOR provides mechanisms such as AI-Powered Collaboration Tools, a PhD program, and training programs. A connectivity fund to support active dissemination across Europe allows the network to grow and support the scientific stepping up of more research groups.




European Commission

# smartNorms4BIM

# Intelligent verification of architectural and construction norms in BIM models

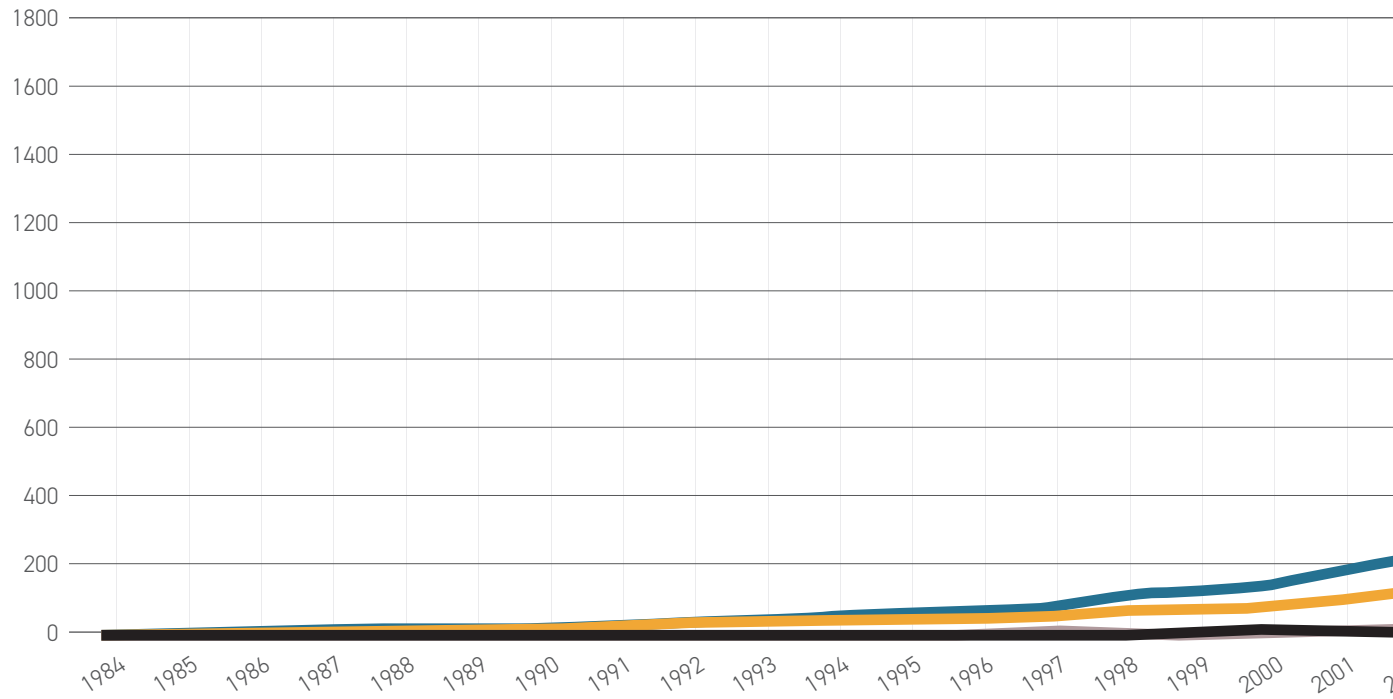
In the field of architecture, engineering and construction (AEC), more and more standards are being used for the digitized representation of the physical and functional characteristics of a building. On the other hand, the regulatory texts that affect this sector are usually expressed in natural language. Therefore, the verification that the design of a building effectively conforms to a certain regulation continues to be an intrinsically manual process, subject to human errors of interpretation, and it requires the experienced consultation of extensive documentation and data relating to the construction. The smartNorms4BIM project aims to innovate through ICT in the verification of compliance with rules and codes in the AEC sector, to make a qualitative leap in the capacity for interoperability between the different agents involved and thus significantly improve the management of projects in this industrial sector. For this reason, an experimental prototype of a tool that demonstrates computational support for the verification task will be developed, combining modelling and information management techniques with artificial intelligence techniques. A small advance in the automation of the process can mean a significant reduction in time, cost and risk of error, in addition to guiding the adoption of those ICT technologies that will lead to a quality and efficient e-government concerning its verification task.

**PI: Marco Schorlemmer**

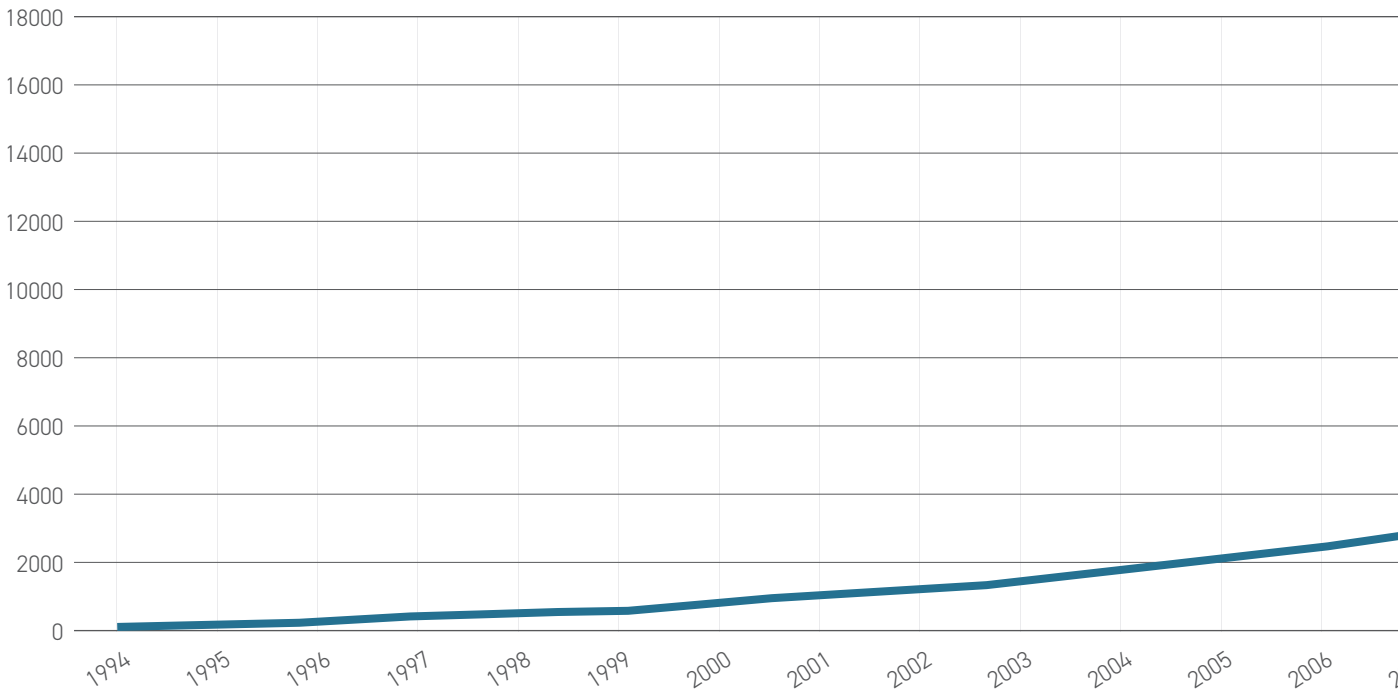
tecnio catalonia | ACCIÓ Generalitat de Catalunya

# Publications & citations

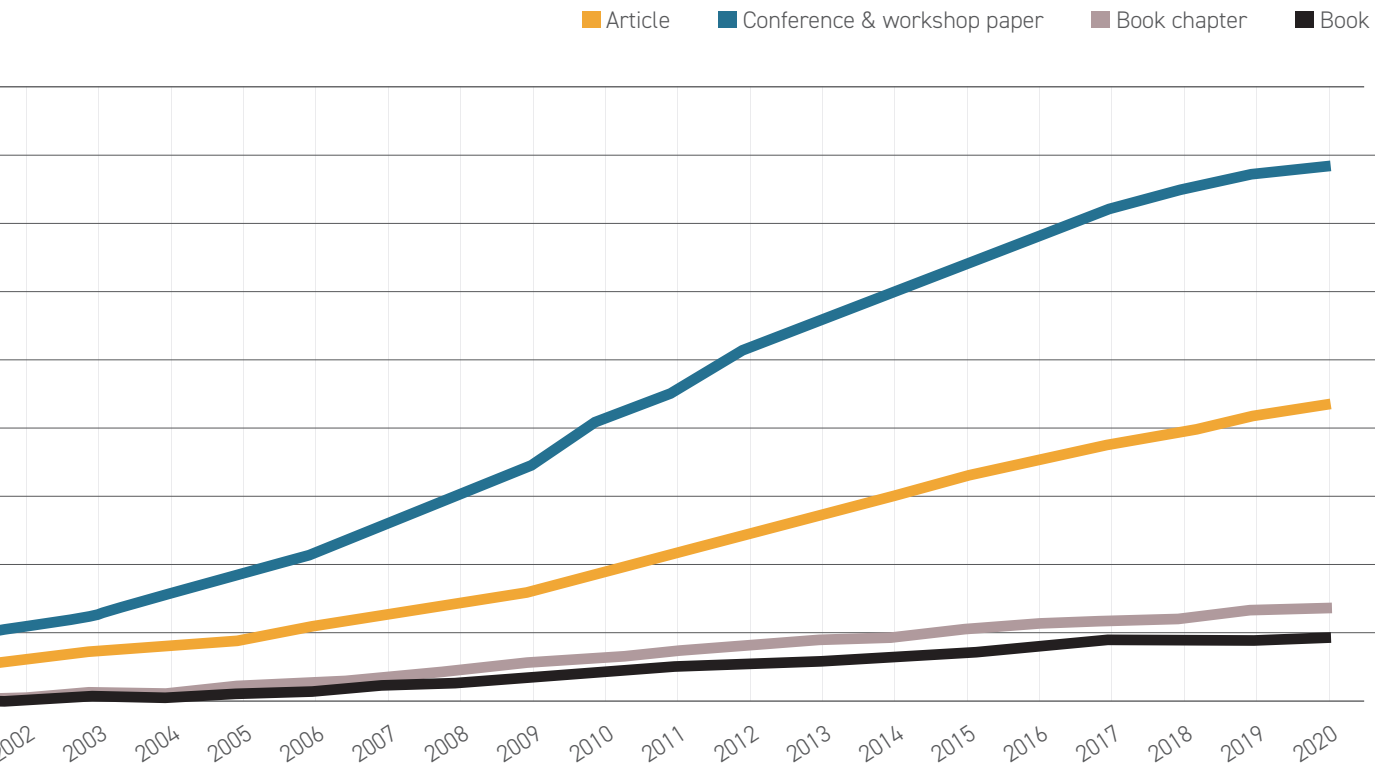
**PUBLICATIONS (2881)**

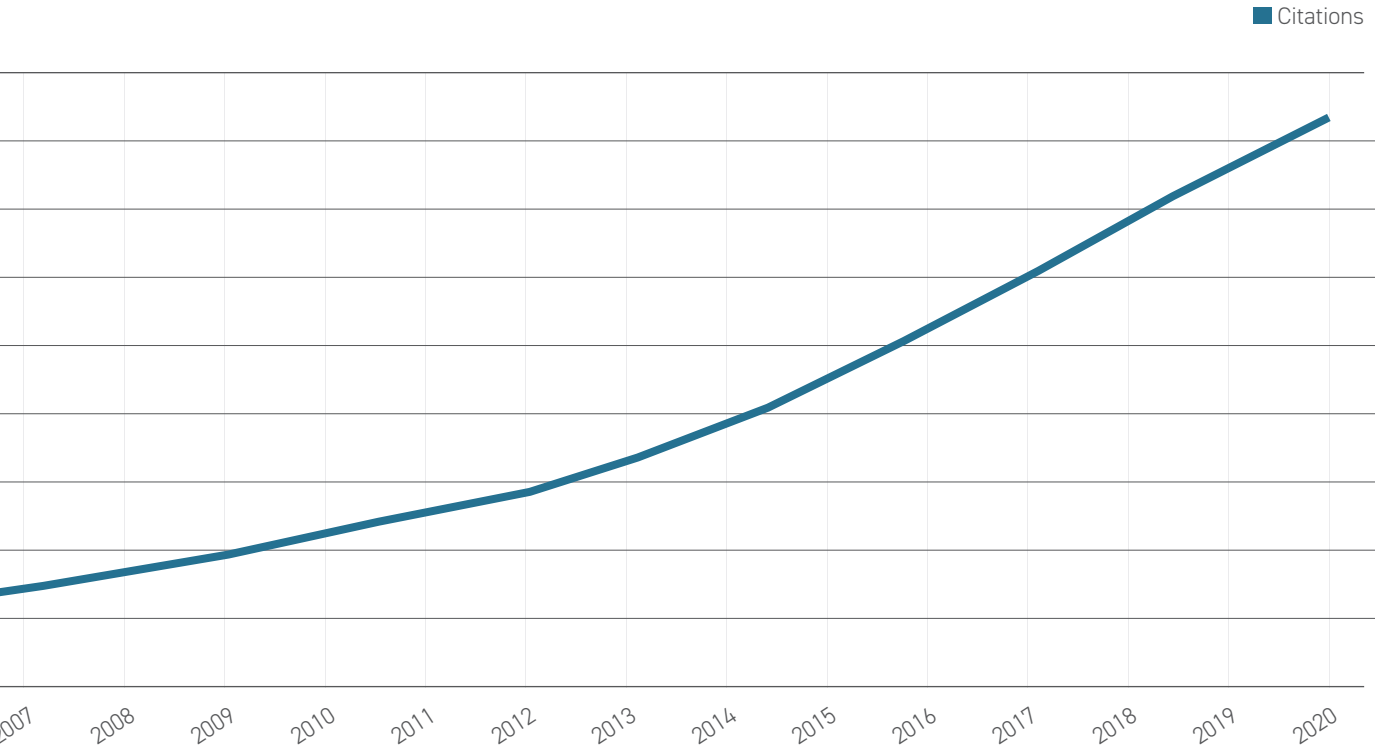



**CITATIONS (WOS)**



IIIA has produced close to 3000 publications, including contributions to conferences and workshops, journal articles and books. In AI, participation in scientific conferences is very important because it is a science that is in constant evolution. Each year, the number of conference and workshop contributions is two times larger than the number of journal publications.



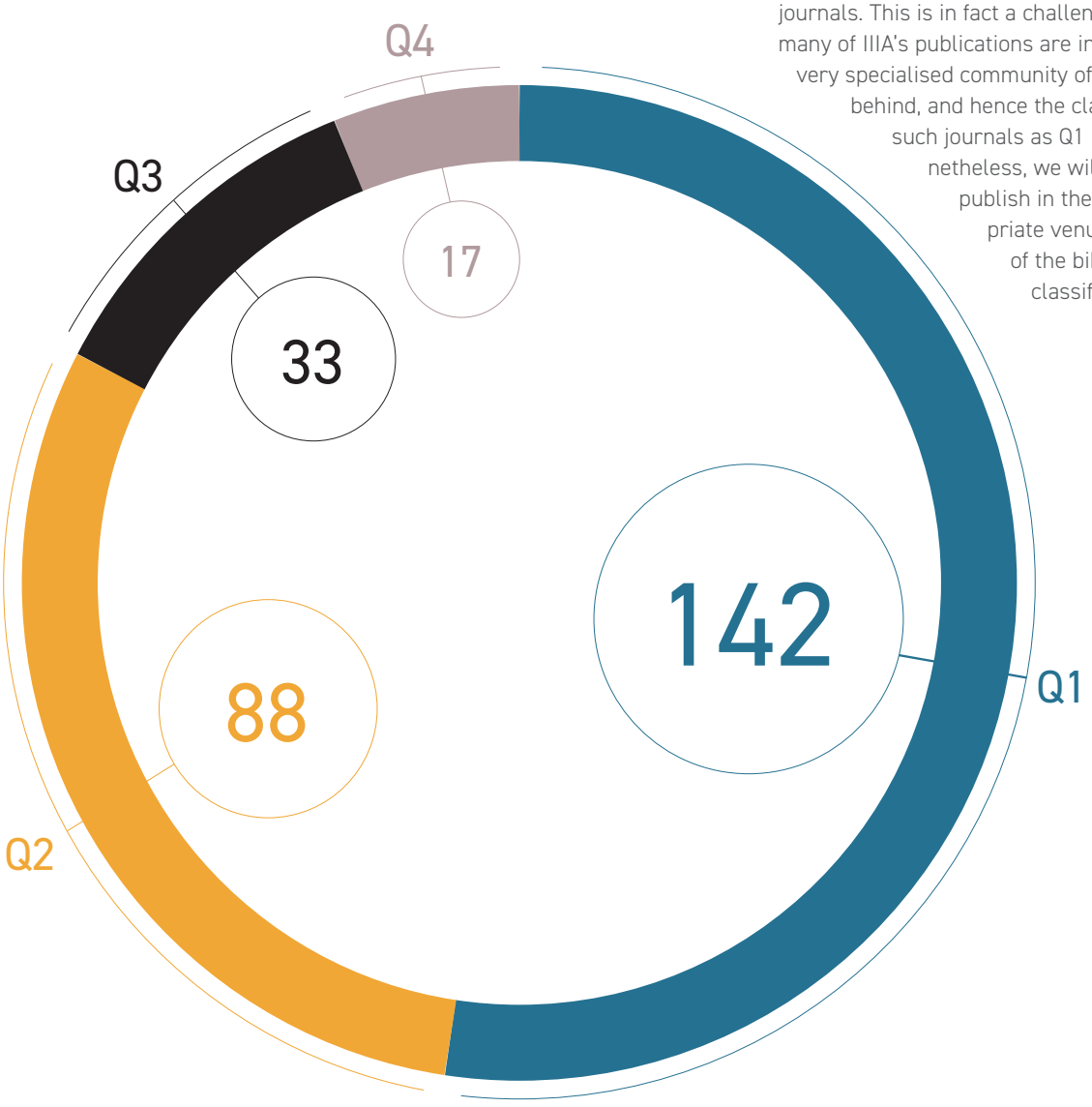



# Journal publications

## QUALITY OF THE PUBLICATIONS IN WELL-KNOWN JOURNALS

IIIA's publications are mostly on fundamental results in AI. One can see in the list of well-knownjournals that focus is precisely on the different theoretical aspects we address, such as logic, machine learning, and agents. Nonetheless, we also publish in some of the most well-known journals in applied AI.

Around 50%of our publications go into Q1 journals. This is in fact a challenge, given that many of IIIA's publications are in areas with a very specialised community of researchers behind, and hence the classification of such journals as Q1 is difficult. Nonetheless, we will continue to publish in the most appropriate venues, regardless of the bibliometrics' classifications.



## WELL-KNOWN JOURNALS (WITH MORE THAN 5 PUBLICATIONS)


280 PUBLICATIONS

# Selected Publications 2020

## PHARAON ANTS INSPIRE AN AI ALGORITHM WITH APPLICATIONS SUCH AS DRUG SEARCH OR LOGISTIC OPTIMIZATION

IIIA scientists improve an algorithm inspired by the behaviour of Pharaon ants. These ants use pheromones for setting 'no-entry' signals, which is an example of learning based on negative feedback. It enables to improve optimization techniques for many sectors, both in industry and in scientific research. In this research, Christian Blum and the doctoral student Teddy Nurcahyadi have designed the first general mechanism to incorporate negative learning to benefit and improve the ACO technique.

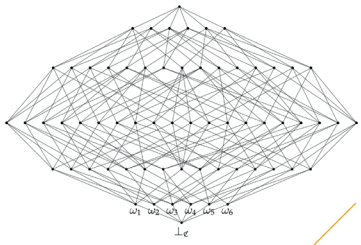
This work won the best paper prize at the ANTS 2020 conference.

The award was this bronze ant by the Italian sculptor Matteo Pugliese.

## A NEW PERSPECTIVE ON CONDITIONAL EVENTS AND THEIR RELATION TO CONDITIONAL PROBABILITY AND LOGIC

Two IIIA researchers, Tommaso Flaminio and Lluis Godo, together with the Italian colleague Hykel Hosni from the University of Milan, have investigated a novel perspective on the rich interplay between logic and conditional probability in the representation of conditional knowledge using a new algebraic structure for conditional events. This work have resulted in a contribution of theoretical nature to the area of knowledge representation and uncertainty reasoning.

The results of this work has been published in the Artificial Intelligence Journal, the most prestigious journal in the field, volume 286, 2020.



The minimal, non-trivial, algebraic structure for boolean conditionals.

## A NOVEL ALGORITHM FOR QUALITATIVE CASE-BASED REASONING AND LEARNING (QCBRL)

QCBRL is a case-based reasoning system that uses qualitative spatial representations to retrieve and reuse cases using relations between objects in the environment. Combined with reinforcement learning, it allows the agent to learn new qualitative cases at runtime, without assuming a pre-processing step. To avoid cases that do not lead to maximum performance, it executes case-base maintenance, excluding these cases and obtaining new (more suitable) ones. Ramon López de Mántaras and his collaborators made an experimental evaluation in different environments: a simulated robot-soccer, a real humanoid-robot, and simple tasks in two different grid world domains. Results show that QCBRL outperforms traditional RL methods. In autonomous soccer matches, the robots performed a higher average number of goals than those obtained using pure numerical models.

This work has appeared in the prestigious Artificial Intelligence Journal, volume 283, 2020.

Experimental evaluation of QCBRL in a simulated robot-soccer environment.

## CLAUSE VIVIFICATION BY UNIT PROPAGATION IN CDCL SAT SOLVERS

SAT solvers are used to solve challenging combinatorial problems thanks to powerful solving techniques as conflict-driven clause learning. Learning new clauses from conflicts reduces the traversed search space if we only keep relevant and short learnt clauses. This paper proposes a new way of eliminating redundant information in learnt clauses that produces significant SAT solvers' performance improvements. This technique has been incorporated into several state-of-the-art SAT solvers. Furthermore, it has allowed to solve some open problems and win an international competition of SAT solvers. This is joint work with Chu Min Li and Yu Li from Université de Picardie, Fan Xiao, Mao Luo and Zhipeng Lü from Huanzhong University of Science and Technology, and Felip Manyà from IIIA.

This work has appeared in the Artificial Intelligence Journal, volume 279, 2020.

Graphical representation of a SAT instance.

## LESSONS LEARNED FROM SUPPLEMENTING ARCHAEOLOGICAL MUSEUM EXHIBITIONS WITH VIRTUAL REALITY

Virtual Reality and 3D reconstruction are effective modern techniques with high potential to help museum visitors better understand the past. Indeed, 3D reconstructions offer cost-effective means to recreate historical settlements in a computer-generated virtual environment. Virtual Reality facilitates immersing people into such environments while providing a high degree of realism. In this work, we present a study using Virtual Reality in itinerant archaeological exhibitions. We also detail novel lessons learned from developing an interactive Virtual Reality simulation of the Neolithic settlement of La Draga. This is joint work with Anna Puig·Inmaculada Rodríguez from the University of Barcelona, Anton Bogdanovych from the University of Western Sydney, Núria Morera and Raquel Piqué from the Autonomous University of Barcelona, Antoni Palomo from the Museum of Archeology of Catalonia, and Josep LL. Arcos, Juan A. Rodríguez and Sergi Cebrián from IIIA.

This work has appeared in the Virtual Reality Journal, the most prestigious journal in virtual reality research, volume 24, 2020.

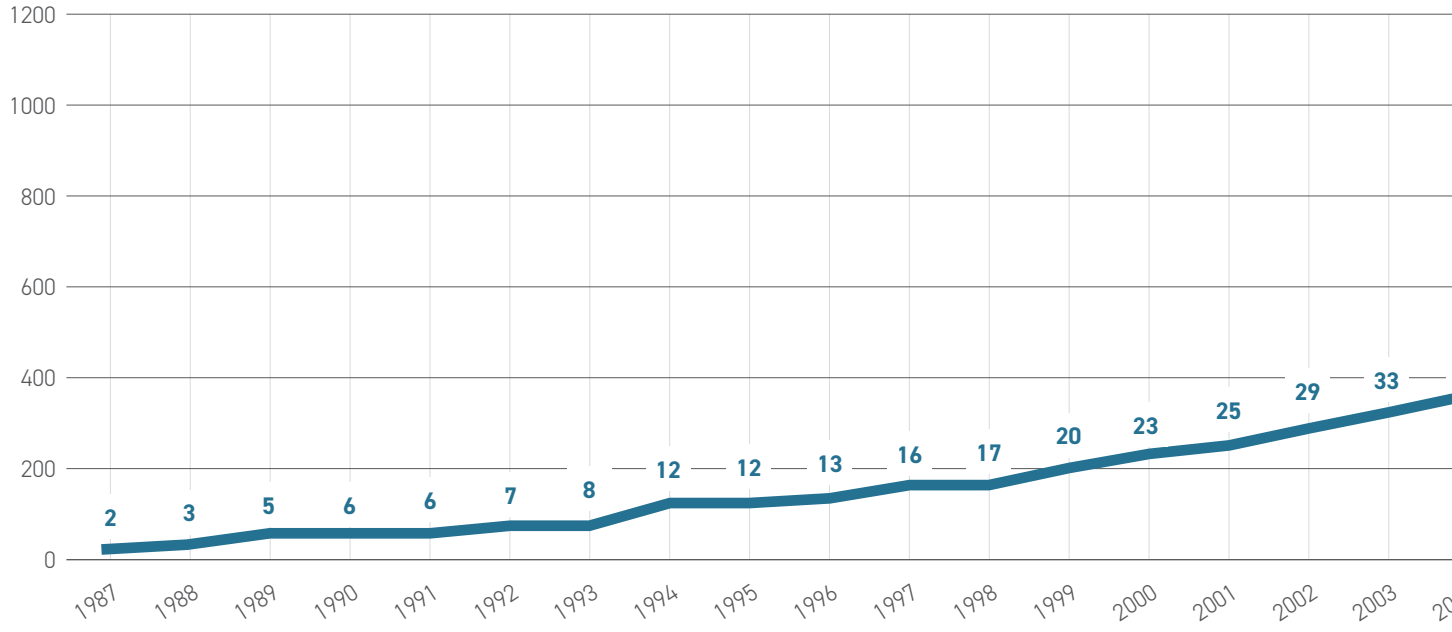

Virtual reality experience at a museum.

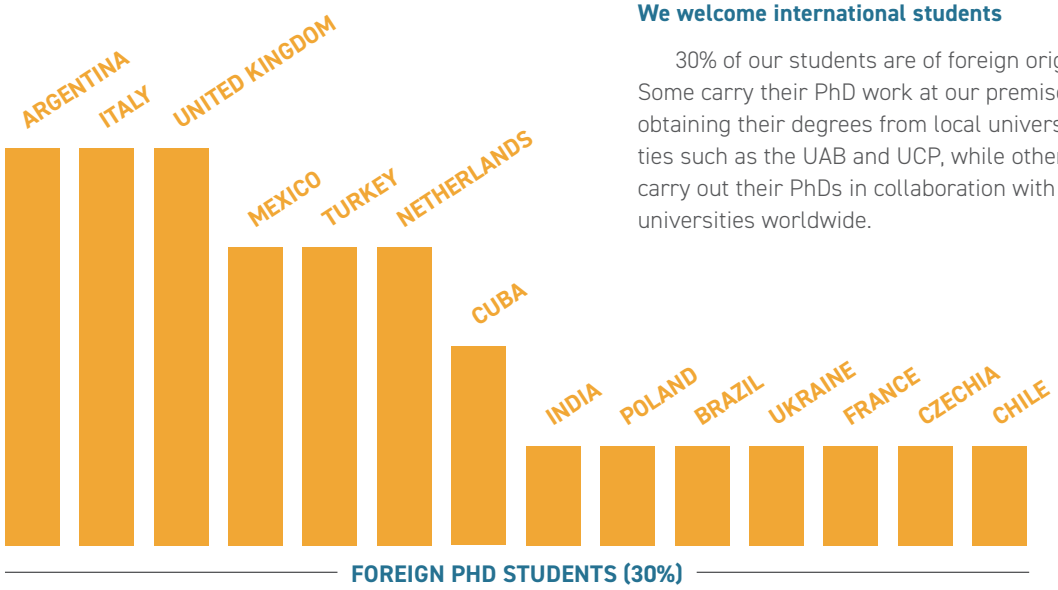
# 100 PhD theses advised by IIIA researchers

### Our students are shaping the future of AI

Training new generations of scientists is a fundamental task of IIIA researchers. Throughout IIIA's history, 100 high-quality theses have been presented on various topics in AI, from mathematical foundations to applied AI covering various domains.

**THESES AT THE IIIA**

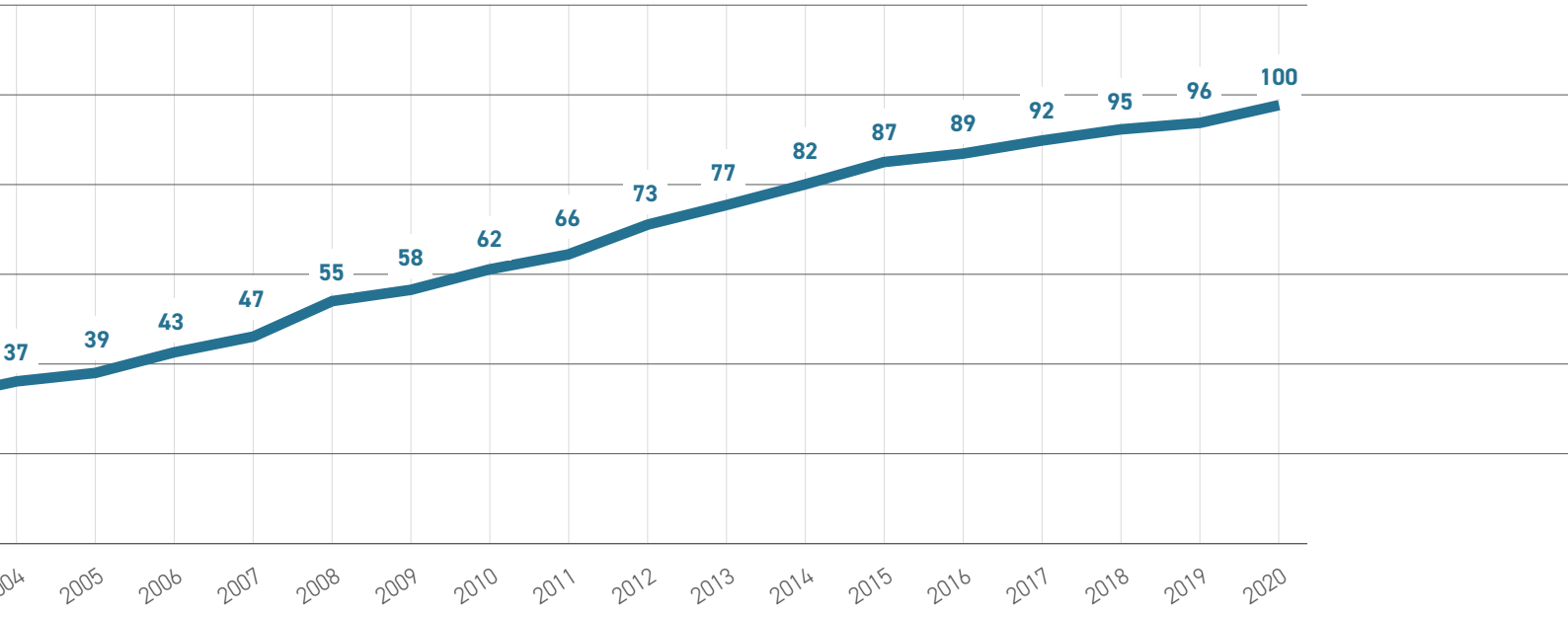



### We welcome international students

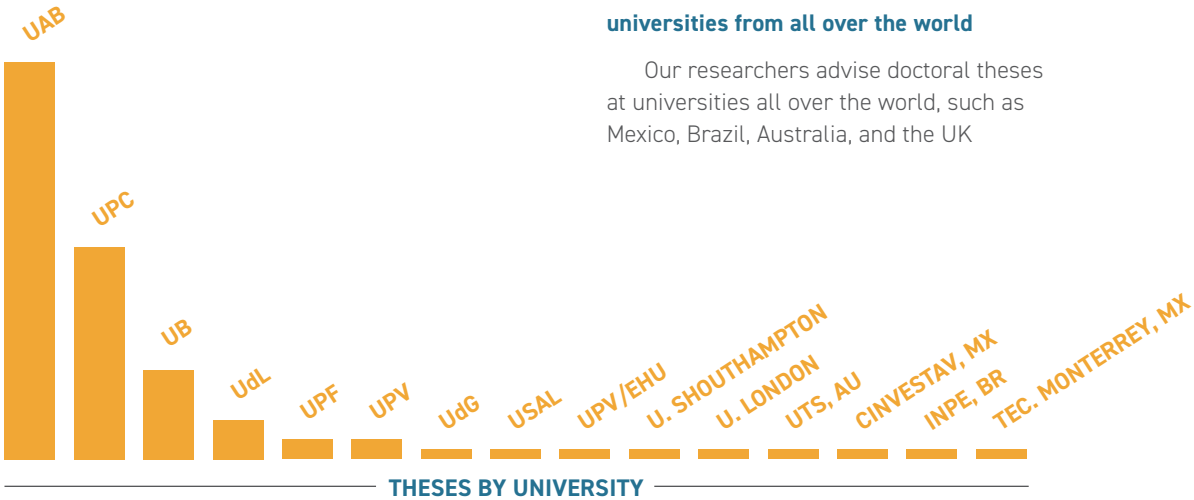
30% of our students are of foreign origin. Some carry their PhD work at our premises, obtaining their degrees from local universities such as the UAB and UCP, while others carry out their PhDs in collaboration with universities worldwide.

Celebrating IIIA's 100th thesis of David Sánchez-Pinsach with some delicious cakes.




**We collaborate with international universities from all over the world**

Our researchers advise doctoral theses at universities all over the world, such as Mexico, Brazil, Australia, and the UK



# Theses 2020

## Mehmet Oguz Mulayim
Advisor —⟐ Josep Lluís Arcos

**Anytime Case-Based Reasoning in Large-Scale Temporal Case Bases**

Case-Based Reasoning (CBR) methodology's approach to problem-solving that "similar problems have similar solutions" has proved quite favourable for many industrial artificial intelligence applications. However, CBR's very advantages hinder its performance as case bases (CBs) grow larger than moderate sizes. Searching for similar cases is expensive. This handicap often makes CBR less appealing for today's ubiquitous data environments while there is even more reason to benefit from this effective methodology. Accordingly, CBR community's traditional approach of controlling CB growth to maintain performance is shifting towards finding new ways to deal with much data.

As a contribution to these efforts, this thesis aims to speed up CBR by leveraging both problem and solution spaces in large-scale CBs composed of temporally related cases, as in the example of electronic health records. When the speed-up we achieve for exact results may still not be feasible, we endow the CBR system with anytime algorithm capabilities to provide approximate results with confidence upon interruption. Exploiting the temporality of cases allows us to reach superior gains in execution time for CBs of millions of cases. Experiments with publicly available real-world datasets encourage the continued use of CBR in domains where it historically excels like healthcare; and this time, not suffering from, but enjoying big data.

## David Sánchez-Pinsach
Advisor —⟐ Josep Lluís Arcos

**Handling Missing Data in Clinical Decision Support**

Deciding which are the best treatments is a complex task when patients suffer multiple impairments and when a multidisciplinary team is involved in the intervention. There is always more than a unique treatment option, and the results sometimes can be viewed in a short period or only be capable of being measured when the treatment is finished. In this context, the design of effective Clinical Decision Support Systems (CDSS) to help clinicians to select the most appropriate interventions is still a challenge.

The amount of available data is not always the same for all patients, especially in early treatment stages, hindering the inference in CDSS. To improve the capabilities of CDSS, different components are proposed within a CDSS framework for long-term treatments. A first component is focused on improving the quality of the inferences in missing data scenarios. The Dynamic Multiple Imputation (DMI) algorithm is presented as an effective methodology for data enhancement in CDSS. DMI is capable of adapting to different scenarios with a low or high percentage of missing data. Several experiments conducted reveal that DMI is competitive with regression problems. A second component is devoted to weigh confidence measures, given the uncertainty associated with missing information, by incorporating Mutual Information measures in confidence existing estimators. Based on a community detection algorithm, a third component is proposed to find relationships between clinical decisions that are not explicit. Finally, to illustrate the applicability of different proposed components, two real clinical use cases with chronic patients are presented, the first in the hospital context and the other in the home context.

## Antonio Perelló Moragues
Advisor —⟐ Pablo Noriega

**A value-based approach to agent-based simulation for policy assessment: an exploration in the water domain**

This dissertation is grounded on the realisation that some significant social problems ---like climate change, poverty-driven migration or water scarcity--- may be framed as policy-making exercises. Following the classical AI approach, the realisation is translated into building artefacts' engineering task to solve these problems with sound theoretical backing and appropriate tools. The dissertation is based on two main premises: (i) that policy-making is a value-driven social process; and (ii) that agent-based simulation is an appropriate methodology to support policy assessment. The contribution is threefold. First, it proposes a conceptual framework to model policy domains and assess the outcomes of policy interventions; such framework provides the means to represent the domain of intervention and the intervention itself, as well as the stakeholders and values involved in the policy and its assessment. Second, it outlines methodological heuristics and artefacts to represent, explore and assess alternative policy interventions. And third, it provides empirical backing to both framework and tools using water use as the policy domain.

The dissertation addresses the following research questions in more concrete terms: (T1) How to represent value-driven social coordination problems. (T2) How to operationalise values so that they can be used and measured in computational models for policy simulation. (T3) How to use agent-based simulation to assess the outcomes of a policy intervention involving multiple values. (T4) What are the key ethical issues involved in using agent-based simulation to support the design and deployment of policy intervention. (T5) To what degree value-driven policy making modelling is a convenient testing problem of the general Value Alignment Problem in AI. (T6). Explore these topics for the water domain.

## Kemo Adrian
Advisor —⟐ Enric Plaza

**A computational model for mutual intelligibility in argumentation-based multiagent systems**

In supervised symbolic learning, examples are related to signs through strict associations. These associations, given by a third party, are considered fixed by intelligent systems that received them. Agent systems with learning capabilities inherit this strict assumption on their example-sign associations. This thesis presents a different approach to example-sign associations for multiagent learning systems. The example-sign associations are instead fluid and adaptive, being able to evolve during communication between two agents. We believe that having strong assumptions about the signs associated with examples prevents agents from effectively communicating in semantic heterogeneity situations. Our approach models elements from semiotics and anthropology allowing the agents of a multiagent system to change their example-sign associations dynamically. Therefore, when they observe disagreements in semantic heterogeneity situations, they can resolve them and reach mutual intelligibility.

This research work is presented in five stages. First, we introduce the problem of reaching mutual intelligibility in scenarios where disagreements are observed. The second stage introduces a semiotic viewpoint that characterizes our approach and allows agents to communicate on their example-sign associations. The third stage is the presentation of an argumentation model that assumes error-free concept learning. The fourth stage extends this model to an error-tolerant argumentation model, which can reach mutual intelligibility while assuming a certain degree of error in concept learning. The fifth stage is presenting two strategies adopting our approach and our argumentation model: the systematic and the lazy strategy. The systematic strategy is one where agents, upon meeting, start arguing about their concepts, to resolve their disagreements all at once. The lazy strategy considers two agents resolving disagreements one by one, as they arise in their interaction. We experimentally evaluate our error-tolerant argumentation model's performances, using both argumentation strategies, and show that agents using our approach can resolve any disagreement, or combinations of them, while increasing their mutual intelligibility. Moreover, we show that the agents can resolve their disagreements and improve their mutual intelligibility in several application domains. Finally, we show that our argumentation model does not require extensive information exchange between agents to attain mutual intelligibility.

# IIIA alumni

**We are proud of our students**

Our alumni usually graduate to become entrepreneurs, hold senior positions at top tech companies worldwide, or continue their academic path with excellence at leading research institutes.

In addition to their academic excellence, our alumni, also value the atmosphere of friendship, cooperation and solidarity that has always been part of IIIA's philosophy.

Here are selected testimonies taken from IIIA's 25th anniversary video.

IIIA - CSIC

**Dave Robertson**
Professor of Applied Logic, Head of College of Science & Engineering, The University of Edinburgh

*"I am deeply grateful actually for all that I have learned from a bunch of people: Jaume Agustí, Carles Sierra, Marco Schorlemmer, Jordi and all the rest."*

**Sarvapali D. Ramchurn**
Professor of artificial intelligence, Centre for Machine Intelligence. University of Southampton

*"I was at the institute for a few months when I was doing my PhD. Thanks for your great hospitability."*

**Isaac Pinyol**
Senior Lead Engineer at Apple Inc. Cupertino CA. EEUU

*"Van ser uns anys molt intensos, molta feina, però uns anys on ens ho passem molt bé i encara continuen sent els millors anys de la meva vida."*

*(Those were very intense years, with much work, but they were years where we had a great time and they continue to be the best years of my life.)*

amazon

**Arnau Ramisa**
Amazon, California

*"Ha estat un privilegi poder formar part d'aquesta gran família i gaudir del bon ambient i la germanor que sempre hi ha hagut a l'institut."*

*(It has been a privilege to be part of this great family and to enjoy the good atmosphere and brotherhood that has always existed in the institute.)*

Google

**Santiago Ontañon**
Senior Research Scientist Google Research Mountain View, CA, USA

*"Una de les coses que recordo amb més afecte és el temps just abans dels concerts de Nadal on ens passaven el temps amunt i avall de cul assajant les cançons que volíem tocar."*

*(One of the things I remember most is the time just before the Christmas concerts where we spent time up and down rehearsing the songs we wanted to play.)*

2σ TWO SIGMA

**Peyman Faratin**
Chief Scientist at Two Sigma Insurance

*"I had a wonderful time with you all. My fondest memory was Carles running through the corridors in his Catalan shoes, shorts and kicking his heels and singing all my brothers are in Africa."*

### DOCTORAL CONSORTIUM

Every year the doctoral consortium serves as a forum for PhD students to share their work with the IIIA community. The main goal is to help students explain their doctoral theses and ensure they are on track.

During the event, every student gets 15 minutes to explain his/her work progress and future plans and another 10 minutes to discuss their work with a committee of three members. Students are reminded that their presentations should be aimed at an audience with knowledge in AI but not necessarily in their specific area of research. They should give particular importance to the impact that the PhD can potentially have. Presentations are in English and are structured to open with an introduction, discuss the research objectives, state of the art, research methodology and work plan, publications and research stages, before closing with the conclusions.

The presentations are followed by a closed consensus meeting where committee members prepare a final report for each student, intended to be constructive and help motivate students in their work.

# Knowledge and technology transfer

UDT-IA
Unitat de Desenvolupament Tecnològic en Intel·ligència Artificial

## UDT-IA

The UDT-IA was created in 2002 as a service of the IIIA-CSIC research lines promoting the transfer of knowledge and technologies from IIIA research to society, as well as promoting and managing collaboration with innovative companies and organizations that want to incorporate AI into their processes. Another of UDT-IA's goals is to act as an observer, detecting innovation needs in business and promoting and disseminating the scientific activity carried out at the institute. The UDT-IA, through different agents and strategies, ensures knowledge transfer to society is carried out at both educational and business level.

In 2020, UDT-IA collaborated on six projects with companies and has helped present five new project proposals, of which three have been accepted. The UDT has also led the protection of three technologies developed at our institute through copyright registration.

Regarding the dissemination and commercialization of IIIA technologies, the UDT-IA has participated in more than 45 events with companies and other entities. We specifically highlight our participation in The Collider OnCampus program with the project "Teams AI Recruiter", in the InnovaFP Hackaton with the pilot Eduteams, in the AI4all.cat with the pilot Edu2Com and the program "Artificial intelligence applied to industry", in the Platform Artificia.pro and in the scientific committee of the "Festa de la Ciència".


The engineers and researchers of the UDT team in 2018.

# We play an active role in Catalonia's technological ecosystem

## TECNIO

ACCIÓ is the agency set up by the Catalan Government (Generalitat de Catalunya) for the Competitiveness of Businesses. Under the TECNIO label, ACCIÓ identifies the developers of the most innovative technologies in the Catalan R&D system with different technological capacities and with the ability to transfer them to the market. This helps companies gain competitiveness by applying new technologies.

Currently, IIIA is a technology developer that was granted the TECNIO label, and we have been part of TECNIO since the beginning of this initiative. This gives us visibility and a competitive advantage for transferring our AI knowledge and technologies to the companies in our environment. An important aspect of TECNIO is that it has some instruments, like INNOTEC and "tech bonus" calls, that facilitate the collaboration between technology developers and industries.

Currently, IIIA is running one INNOTEC project with the company EiPM.

## PRUAB

The UAB Research Park (PRUAB) is a non-profit organization created in 2007 by the Autonomous University of Barcelona (UAB), the Spanish National Research Council (CSIC) and the Institute of Research and Technology (IRTA). Its mission is to promote and enhance the technology and knowledge transfer activities of its members, encourage entrepreneurship by creating new businesses based on research and generally facilitate interaction between research, business and society.

The Research Park provides services to UAB's research departments, centres and institutes located on the Bellaterra campus, such as the IIIA. They all carry out their activities around six core themes: Biotechnology and Biomedicine; Food Technology and Animal Health; Materials Science and Energy (nanotechnology and microelectronics), Information Technology and Communications; Social Sciences and Humanities; and Environment and Climate Change.

The PRUAB facilitates and promotes the transfer of knowledge generated by the research groups of the UAB sphere, as well as their R&D capabilities to help the innovation needs of the economic and social environment. PRUAB's vision is to become the reference organization for companies and researchers, and act as an engine of economic and social development.

## DIGITAL CLUSTER

The Digital Cluster is a meeting space formed by a group of companies, entities, and research groups related to the ICT field and belonging to Catalonia Clusters' association.The cluster brings together start-ups, SMEs and large companies, research centres, and other entities to boost the Catalan ICT sector's competitiveness, promoting a new business culture based on collaboration and open innovation.
It promotes the generation of knowledge and the stimulation of innovation and research. These activities are crucial for the generation and acceleration of innovative projects. Cluster members share experiences and expertise around ICT topics, implement technology transfer mechanisms, and understand and apply innovation methodologies.The IIIA has been an active member of the Digital Cluster since its inception.

## SPIN-OFFS

AOur first spin-off, **ISOCO**, was set up in 1999 dedicated to intelligent software components for Internet-related applications. Today, ISOCO is a leading company within its sector in Spain. **STRANDS** started in 2004 dedicated to recommendation systems, particularly in the finances sector, which is also a leading company in Spain today. **COGNICOR** was founded in 2011 based on a large, over five million Euros, project called "Agreement Technologies". This company develops software products to automatically resolve customer complaints using machine learning and case-based reasoning techniques. COGNICOR has received several awards, including the prestigious "2012 European Union Tech All Stars Competition".

# Intellectual Property Protection

### Synergistic Team Composition

Synergistic Team Composition is a computational method that splits a group of people into different teams. Each team has to be diverse in terms of personality and gender, while at the same time, they cover the required skills to carry out a particular task. Besides, teams must be balanced in size, which means that each team will have a similar executive capacity.

### Virtual Reality Development Environment of a Neolithic Archaeological Site

RVLaDraga software package contains all the audio-visual elements (3D objects representing the physical space, the architectural elements and the characters) and the programmatic elements (source code) that allow the execution of a serious game, a video 360 and other interactive experiences of the La Draga archaeological site. Besides, it allows for adding new layers of development for the creation of new interactive products. Thus, it is possible to use the source code of the application and continue its development in Unity.

### Intelligent Information Technologies to facilitate the development of mutual-help communities

uHelp provides a distributed community-based application for building a community of helpful people and supporting community members find the appropriate help within their social network. uHelp's novelty is its trust-based intelligent search for volunteers. Trust is crucial in such innovative social applications, and uHelp's intelligent search for volunteers is based on a number of AI technologies: (1) a novel trust-based flooding algorithm that navigates one's social network looking for appropriate trustworthy volunteers; (2) a novel trust model that maintains the trustworthiness of peers by learning from their similar past experiences; and (3) a semantic similarity model that assesses the similarity of experiences.

### Trust Component Based on Information Theory

Our TrustIt component finds, in a distributed open system, the most suitable entity to collaborate with—understanding as an entity a software agent, a person or a web-service. TrustIt can be used to automatically calculate one's trust in an entity concerning a potential future commitment by assessing the past performance of the entity. The component is meant to be used in scenarios such as networked organizations, social networks or online communities. TrustIt can be applied to any real-world application where past commitments are recorded and observations are made to assess those commitments. TrustIt is already being used in industry.

# To patent or not to patent?

Software patents are not straightforward, unlike classical industrial patents that patent physical machines or industrial processes. Software patents do not have a single legal definition worldwide. In Europe, computer programs themselves are not patentable unless they produce material effects that are often difficult to define. The legal registration of programs as intellectual property is an alternative way to provide some protection against misuse. This is the option usually adopted by IIIA to protect its software. Agreements must be in place for third parties to use our software, generally in the form of providing financial compensation.

### Computational Method for large-scale RIDEsharing

CoMe4Ride is a hybrid optimization method that provides a solution for large-scale online ride-sharing in real-world scenarios. The method is implemented as an algorithm, and it is integrated into a simulation tool.

### Context-Aware human Activity REcognition in cluttered data

CAARE is a component that addresses the problem of detecting patterns of activities of daily life (ADL) that can lead to health or social issues, such as sick leave, lack of autonomy, social isolation or rejection. The system is based on an original combination of techniques that provide activity recognition with high accuracy based on activity data from wearables or other sources.

### Collaborative Assessment

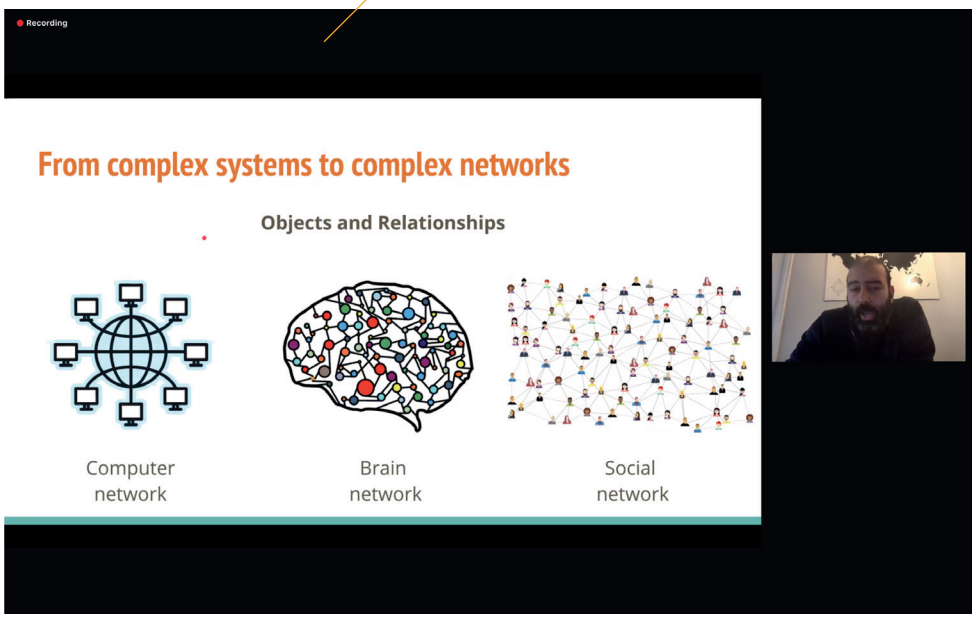
COMAS is a component that recommends a grade for a student's assignment. Taking into account the evaluations made by other members, COMAS generates the grade automatically. In general, it addresses the problem that appears when many objects need to be evaluated. For example, a professor in an online course (MOOCs) needs to assess a large number of students; or the coordinator of a large conference needs to decide the final evaluations of the articles reviewed; or a buyer in an e-commerce site needs to get an opinion on the products offered.

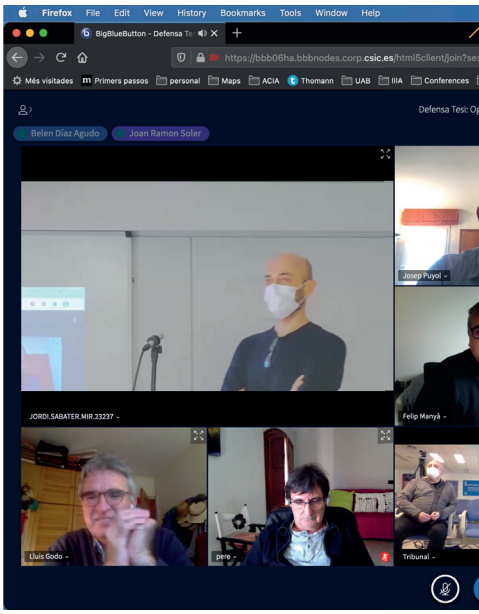
### Components based on optimization and multi-attribute decision mechanisms for a strategic recommendation

goStrategic is a component for quick solutions to the problem of strategic decision making. It offers the possibility of carrying out automatic analysis that allows giving answers in real-time to questions that an organization or business has to address for its improvement. For example, what changes must business entities make to their action plans to reach a set business objective? Why can't business entities achieve a business objective? What parameters should be made more flexible in your action plans to get closer to the defined goal? What is the best distribution of the budget between different business entities to obtain an optimal business result? Etc.

# Seminars

"Complex Networks Generation: from Probabilistic Models to Deep Generative Approaches", an online seminar by Jesús Giráldez Crú from the Andalusian Research Institute DaSCI, University of Granada.



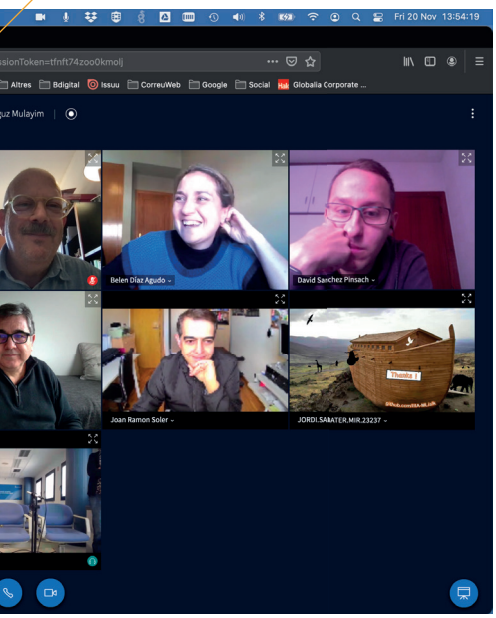
## SEMINARS

IIIA has a long tradition of running seminars on a regular basis. Seminars are our research staff's (researchers, post-docs, PhD students, ...) primary mechanism for sharing their latest research work with the institute, as well as with researchers in other institutes and the public. They are also used as a grandstand for international researchers that visit the IIIA to present their work. Finally, specialized internal seminars help improve personnel training in different areas, like administrative procedures, technical skills, or infrastructures, among others.

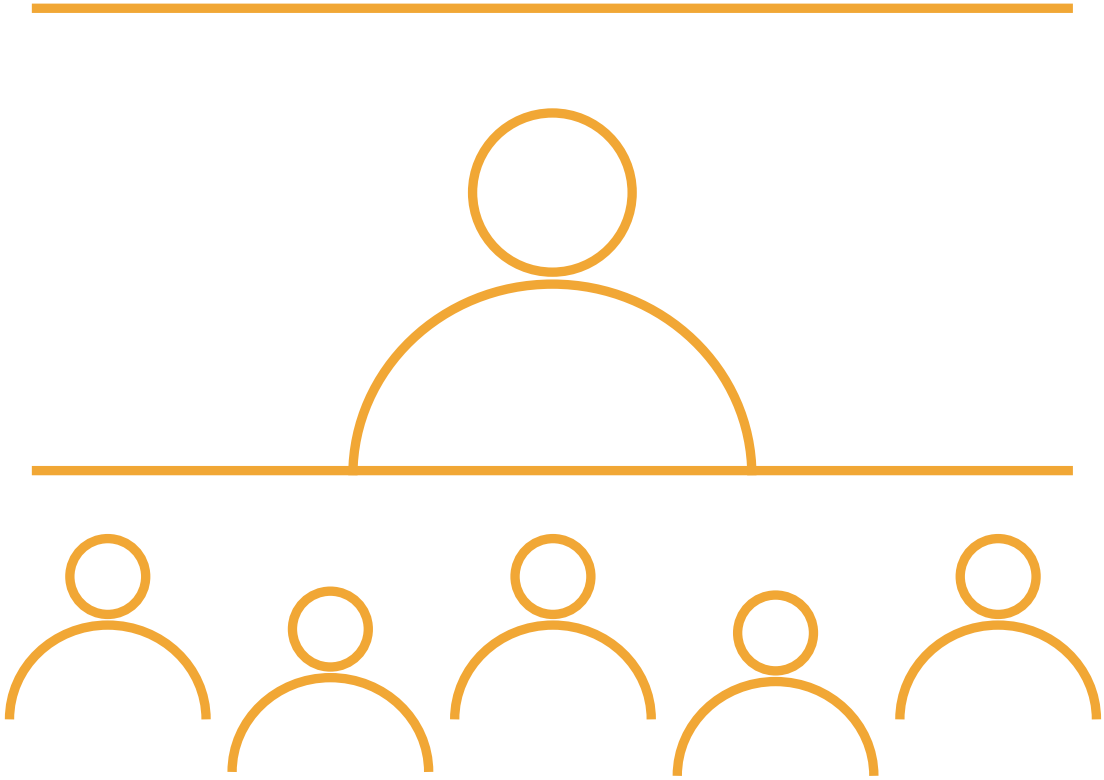
In 2020, and due to the COVID-19 pandemic, we have had to adapt to the circumstances. We have transformed our face-to-face seminars into webinars. We have ran 20 webinars in 2020, where we have presented different ongoing IIIA projects and research work, invited prominent international researchers to present their work, and had introductory presentations of other research centres. The webinar format allows us now to reach more people.

In parallel, we have also been working on adapting the seminar room, so that when we come back to our face-to-face seminars, we can continue to stream them over the internet.

"Anytime Case-Based Reasoning in Large-Scale Temporal Case Bases", an online PhD defence by Mehmet Oguz Mulayim




"Agent Goal Recognition, Path Planning, and Deception", a seminar by Sebastian Sardina from RMIT University, Melbourne, Australia

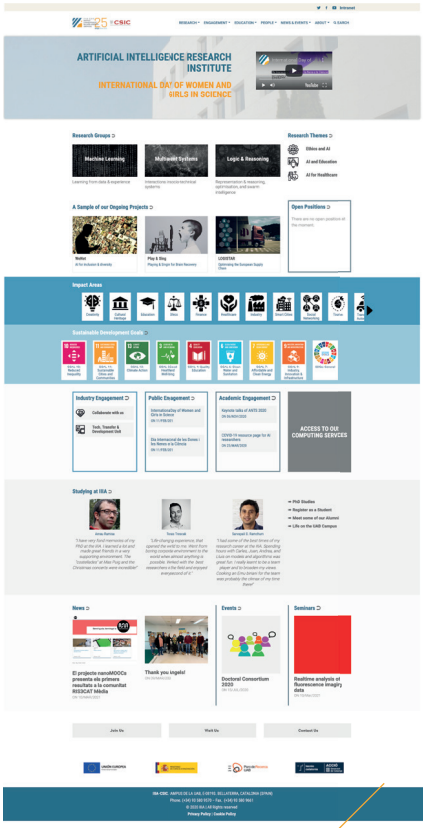
# Social networks

## Scientific communication and democracy

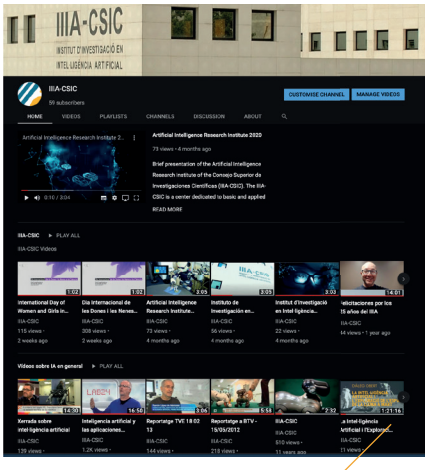
For IIIA, it is very clear that science communication is essential for developing a well-informed society with a critical spirit.

This becomes even more critical when AI is a hot topic for media outlets. It is our duty to ensure news is reflecting the reality of AI research, and presenting the dangers and the virtues of AI without a sensationalist bias.

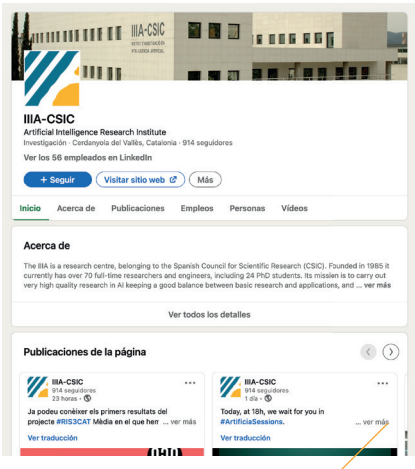
We are actively present on the leading social networks: LinkedIn, Youtube, and Twitter. We are often featured on TV, radio, and other news outlets, addressing a broad audience outside our usual scientific community. Our website has lately been redesigned to engage people from the industry as well as the public at large, in addition to people from academia and research. Other than the news and events sections of our web, you will find engagement sections dedicated to the public and industry.




www.iiia.csic.es



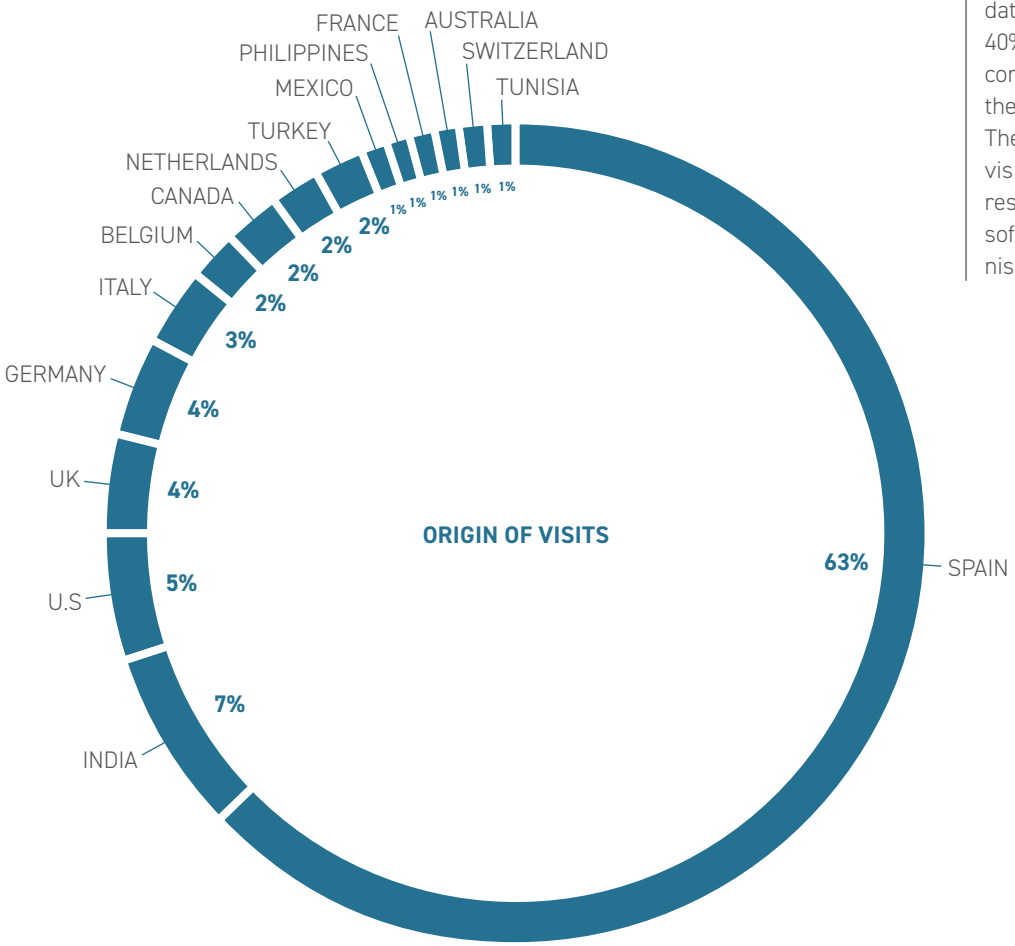

IIIA Channel

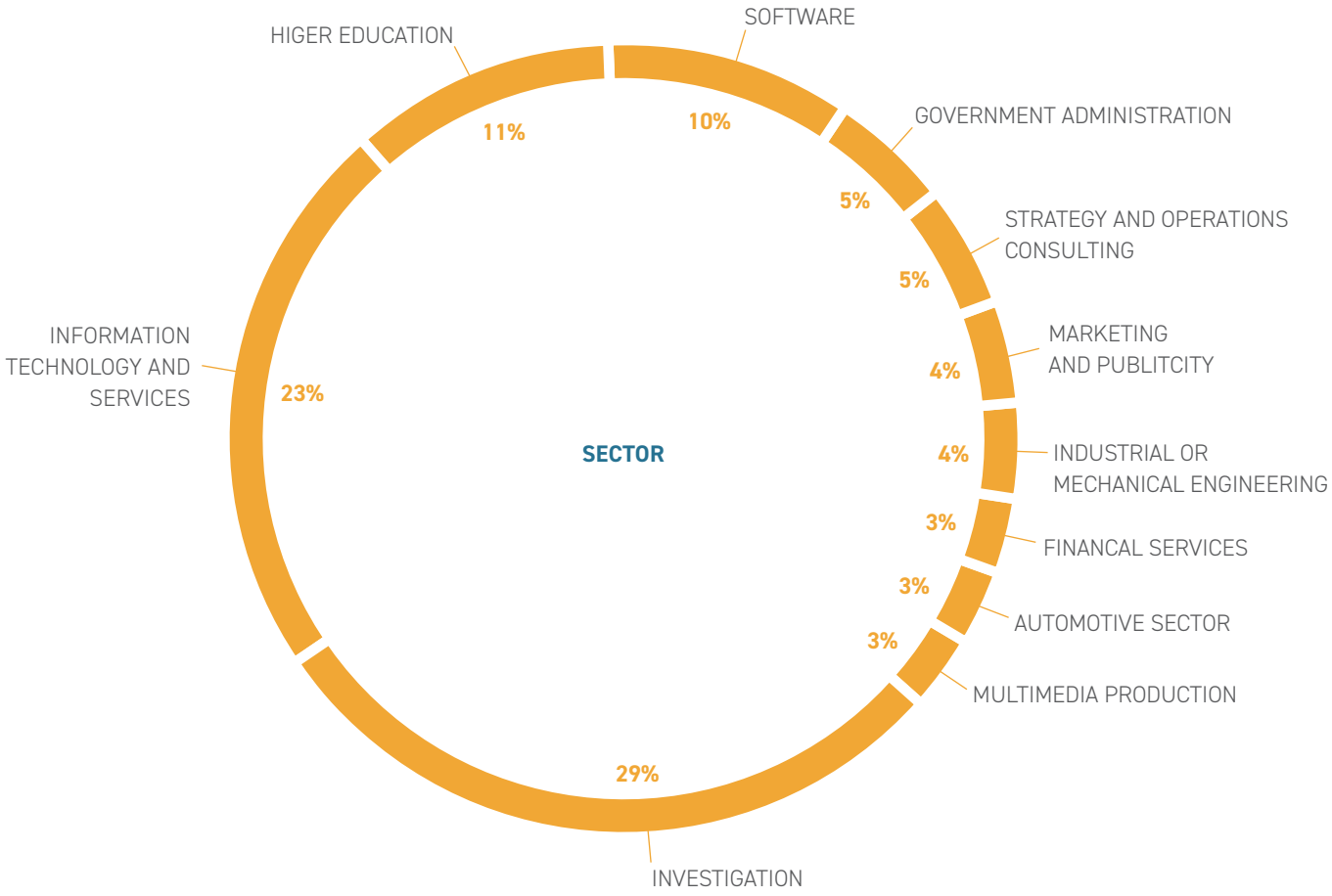



@IIIACSIC


@iiia-csic

An analysis of Linkedin data shows that almost 40% of visits are foreign, coming from Europe and the rest of the world. The most prominent visitor sectors (75%) are research, ICT, education, software, and public administration.

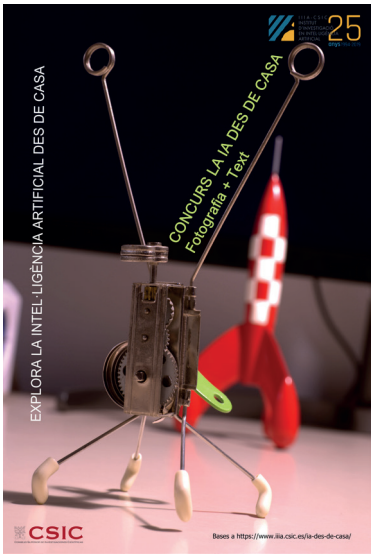


# Activities for youth

**The IIIA actively collaborates in activities to promote scientific vocations among young people.**

We participate in the most important fairs held in Barcelona such as YOMO (The Youth Mobile Festival) organized by MWC, the Setmana de la Ciència, Maker Faire, Exporecerca Jove, Festa de la Ciència, and the Saló de l'Ensenyament. We also participate in CSIC activities such as Inspiraciencia (a literary contest) and CSIC al Aula (training for secondary school teachers). We have created material for young people on our website during the confinement of COVID19. We collaborate with the programs of the La Pedrera Foundation for high-level training for high school students. We also receive visits from high school students in our facilities, and advise students in their research projects at the end of high school.


Fundació Catalunya La Pedrera

SALÓ DE L'ENSENYAMENT
SETMANA DE LA FORMACIÓ I TREBALL

Barcelona Maker Faire
October 5th & 6th 2019

EXPO XXI RECERCA JOVE

EL CSIC A L'AULA
Curs 2019-2020

YO MO BARCELONA

It is a pleasure to see children's interest in science. IIIA at YOMO 2019, in collaboration with ACIA.

# Towards the future

The future of the IIIA looks very bright. Partly, because the area of Artificial Intelligence, our research area, looks more promising than ever. AI will transform every part of our lives. The IIIA is ready and well equipped to contribute to that massive societal transformation. IIIA is one of the main players of the international AI research community and we are the protagonists of many ongoing influential AI activities.

Within the CSIC, we are leading the organisation of the network of research groups working on AI, informally called AIHUB.CSIC. We are forging a strategic agreement with the main Catalan actors in AI called Artificial Intelligence Research Alliance, AIRA.CAT. We are strongly supporting a new degree in AI at the Autonomous University of Barcelona starting in September 2021. We are also strengthening our communication and outreach activities, publishing more multimodal content on our web, and broadening our seminars' topics to have a more multidisciplinary AI view. We face the future with energy and resolution.

IIIA wants that AI is used for good and aims at a trustworthy AI. We are open to new collaborations with research groups worldwide that share these values. Please join us on the road to make AI an enabling technology to change the world and achieve the Sustainable Development Goals of the United Nations.

ANNUAL REPORT 2020

# 20

IIIA-CSIC