
CATALONIA'S ARTIFICIAL INTELLIGENCE STRATEGY

Basic Document

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1. Introduction

Artificial intelligence (AI) is advanced digital technology that enables machines to reproduce or exceed some of the skills that require intelligence when performed by humans. This includes technologies that give machines the ability to learn and adapt, hear and interact, reason and plan, optimise procedures and parameters in order to extract knowledge from huge amounts of data and operate autonomously.

Artificial intelligence is a reality that is already influencing people's decisions, safety, marketing and communication strategies and even medical treatments. Although machines do not have generalist intelligence yet and neither has it been possible to give them common sense, they possess intelligence for very specific tasks that surpass the efficiency of human intelligence. This is creating an enthusiastic surge in the adoption of this discipline in many areas of our lives, although the ethical and legal impacts have not been evaluated in depth, a fact that poses a risk.

In recent years, artificial intelligence has become one of the most significant technological trends with a cross-cutting capacity to change many areas: society, economy, industry, culture, ecology, mobility, public administration and ethics and its cross-cutting nature implies having to consider all the possible stakeholders. The contribution and convergence of different views is both enriching and necessary for the sustainable and comprehensive development of artificial intelligence.

The artificial intelligence sector is expected to grow considerably between 2020 and 2030. According to estimations, by 2021 80% of online interactions between smart bots,¹ powered by artificial intelligence, and humans, by way of chats or applications that operate with the voice, will be automated, thus offering a unique and personalised experience. The same year, over 90% of companies around the world are expected to have adopted some kind of solution or AI application. Some of the most notable applications will be in the field of cybersecurity, business intelligence, market analysis, among others.

In this regard, several countries have already implemented an AI strategy, under which they orchestrate strategic investments to boost their artificial intelligence capabilities. These countries include the United States, Israel, Canada, China, Singapore, South Korea, India, New Zealand, and in Europe, the United Kingdom, France and Finland. They all have similar strategies that coincide with the ethics of their applicability, the significant role that has to be played by public services and the need to promote research, training, and academic and entrepreneurial talent.

Along these lines, on 25 April 2018, the European Commission adopted its artificial intelligence strategy for Europe² which marked the start of a coordinated plan with Member States to encourage the development and use of artificial intelligence in Europe. Within this framework, the Commission requested Member States to approve their respective national AI strategies and focus them on four key areas: increase investment, make more data available, foster talent, and ensure trust in AI.

¹ A bot (a diminutive of robot) is a program that imitates human behaviour, which performs automated tasks and communicates with users. The level of sophistication of the integrated AI can vary, depending on the nature and number of tasks it performs.

² https://ec.europa.eu/spain/barcelona/news/press_releases/180425_ca.

Coordination needs to be stronger to convert Europe into the world leader of the development and implementation of advanced, ethical and safe artificial intelligence.

Catalonia has a long history as a leader in technological innovation and talent development, starting with the first industrial revolution and the first railway, which included achieving numerous social, industrial and economic milestones, and ending up in this specific field with the creation of the MareNostrum,³ one of the most internationally renowned supercomputers. The Barcelona Supercomputing Center has recently received funding from the EC to build the MareNostrum 5, which will multiply the machine's current power by 17 and convert it into Europe's most powerful supercomputer. Catalonia is also a leader in the field of artificial intelligence, demonstrated by the excellent scientific and academic community of international prestige, which places Catalan universities, research and technology centres at the forefront of this field in Europe.

This document clearly shows that Catalonia has the capabilities and potentialities to place the country in a privileged position to lead the development and adoption of artificial intelligence in Southern Europe and convert it into a global technological pole of attraction in artificial intelligence; for these reasons, the government of Catalonia has put priority on preparing the Catalan Artificial Intelligence Strategy and setting it into motion.

The Catalan Artificial Intelligence Strategy is an initiative coordinated by the Catalan ministry of Business and Knowledge, with the participation of the different ministries of the government of Catalonia. The Strategy will deploy a multi-sectoral, cross-cutting people-centred plan that prioritises sectors such as health, mobility, sustainability, productive economy, the agri-food sector and public services, and it will be established in an action plan that revolves around the pivotal elements listed below.

- **Ecosystem:** promote a governance model that supports the development of a coordinated ecosystem of artificial intelligence connected to the rest of the world;
- **Research and innovation:** boost research and innovation by applying specific instruments and establishing synergies among public authorities, specialised research and innovation centres and organisations that use artificial intelligence intensively;
- **Talent:** create, attract and retain specialised talent that fosters the development of artificial intelligence solutions and transfer of knowledge to society, while training citizens and professionals of other sectors to be ready for its impact;
- **Infrastructure and data:** have the necessary infrastructures for the development of artificial intelligence and provide secure access to public and private data;
- **Adoption of artificial intelligence:** promote the incorporation of artificial intelligence to drive innovation in public administration and strategic sectors, including agri-food, healthcare and well-being, the environment, mobility, tourism, culture and industry;
- **Ethics and society:** promote the development of ethical artificial intelligence that respects applicable legislation, is compatible with our social and cultural norms and focuses on people.

³ <https://www.bsc.es/ca/marenostrum/marenostrum>.

The Strategy was drawn up by a working group that, besides members of the government, counted on the participation of some of the country's most relevant artificial intelligence experts, who gave their opinion of the current situation and future development of artificial intelligence in Catalonia. The experts who formed part of the group were specifically:

- Prof. Dr Ricardo Baeza-Yates, CEO of NTENT, director of Graduate Data Science Programs at Northeastern University in Silicon Valley (US) and professor of Information Technology at Pompeu Fabra University (UPF)
- Prof. Dr María Casado, professor of Philosophy of Law, director of the Observatory of Bioethics and Law, UNESCO chair in Bioethics. Faculty of Law at Barcelona University
- Prof. Dr Ulises Cortés, of the Computer Science Department of the Polytechnic University of Catalonia (UPC). Scientific coordinator of the Barcelona Supercomputing Center of the High Performance Artificial Intelligence Group
- Dr Sergi Figuerola, Chief Technology and Innovation Officer of the i2CAT Foundation
- Prof. Dr Karina Gibert, professor of Intelligent Data Science and Artificial Intelligence Research Center (IDEAI-UPC), Vice Dean for Big Data and Data Science of the Official Professional Chamber of Informatics Engineering of Catalonia (COEINF)
- Prof. Dr Elisabet Golobardes Ribé, professor and researcher of Artificial Intelligence and Data Science. Engineering Department, La Salle - Ramon Llull University
- Dimosthenis Karatzas, associate director of the Computer Vision Centre
- Dr Josep Lladós, director Computer Vision Centre
- Prof. Ramon López de Mantaras, director of the Artificial Intelligence Research Institute (IIIA-CSIC). Assistant professor at the Western Sydney University and University of Technology Sydney.
- Dr Josep Maria Martorell, associate director of the Barcelona Supercomputing Center
- Joan Mas, director of the Digital Technologies Division at Eurecat
- Dr Marc Torrent Moreno, director of the Big Data Centre of Excellence in Barcelona. Eurecat
- Prof. Dr Oriol Pujol, Vice-Rector for Digital Transformation at Barcelona University

The working group's conclusions formed the basis of Catalonia's Artificial Intelligence Strategy, known as CATALONIA.AI, which considers everything Catalonia contains, offers and makes available to become an internationally recognised example of successful artificial intelligence deployment, without forgetting the policies that the government of Catalonia will set in motion to accomplish the objective.

This document starts by explaining what artificial intelligence is and describes its impact on society and the present status of its deployment at an international level. It then provides an analysis of Catalonia's current capabilities in this field and ends by describing the goals and actions associated to the different areas of activity of CATALONIA.AI, which foresees the work carried out jointly by public and private sectors, the academic sector, research and innovation centres, organisations, foundations and international bodies to ensure an ethical development of artificial intelligence in Catalonia, which translates into a social and economic improvement for the country and its citizens.

2. Artificial intelligence and the impact of its deployment

2.1 Artificial intelligence

Artificial intelligence is a branch of computer science, dedicated to the development of algorithms, that enables a machine to make intelligent decisions, or at least behave with a human-like intelligence. AI shares concepts and techniques with other academic disciplines, such as mathematics. The concept of artificial intelligence is defined in many ways, although the most common definition was given by John McCarthy, who in 1956 affirmed that 'it is making a machine behave in ways that would be called intelligent if a human were so behaving'. On the other hand, Andreas Kaplan and Michael Haenlein define artificial intelligence as 'a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation'.

Artificial intelligence can be applied in an endless number of fields and sectors; its potential contributions –some of which are already in use and are very significant– mean its development and applicability involve disciplines such as ethics, law, psychology, philosophy, economy, digital marketing, engineering, healthcare, sociology, biology and many others. For this reason, one of the most important and consequential values of artificial intelligence is the work of multi-disciplinary teams, with different views but seeking the same goal.

The multi-disciplinary nature of artificial intelligence is just one of its characteristic features, as mentioned above, but there are more: the capacity to catalyse solutions to different kinds of problems, the close tie with computational capacities, the need for sufficient and accurate data and, finally, human talent and creativity to achieve the desired goals.

Artificial intelligence is one of the disciplines with the greatest power and influence over the model of society and economy in the future and this transforming power will have a notable effect on economy. According to studies, in 2030 artificial intelligence will increase the gross world product by an additional 15.7 billion dollars⁴ and in Spain, it could increase the GDP by 0.8%. As regards employment, the conception of jobs, work and industrial processes, the same as in the case of education and all public services in general, will have to adopt new models and consequently undergo a transformation.

The change is already underway and governments and public authorities need to exercise the responsibility that corresponds to them, fostering and adopting an extensive use of artificial intelligence and putting priority on ethics, so as to improve people's well-being, ensure security in solutions development, protect natural resources, eliminate gender inequality, provide access to technology and information, while guaranteeing transparency and preventing undue use of data and/or algorithms.

In this regard, several countries already have an AI strategy that they use to orchestrate strategic investments, aimed towards boosting their artificial intelligence capabilities. These countries include

⁴ 'Sizing the prize. What is the real value of AI for your business and how can you capitalize', drawn up by PwC.

the United States, Israel, Canada, China, Singapore, South Korea, India, New Zealand, and in Europe, the United Kingdom, France and Finland. They all have similar strategies that coincide with the ethics of their applicability, the significant role of public services and the need to promote research, training, and academic and talent. These strategies are strongly supported by a budget that mostly comes from public institutions, but with a notable private component.

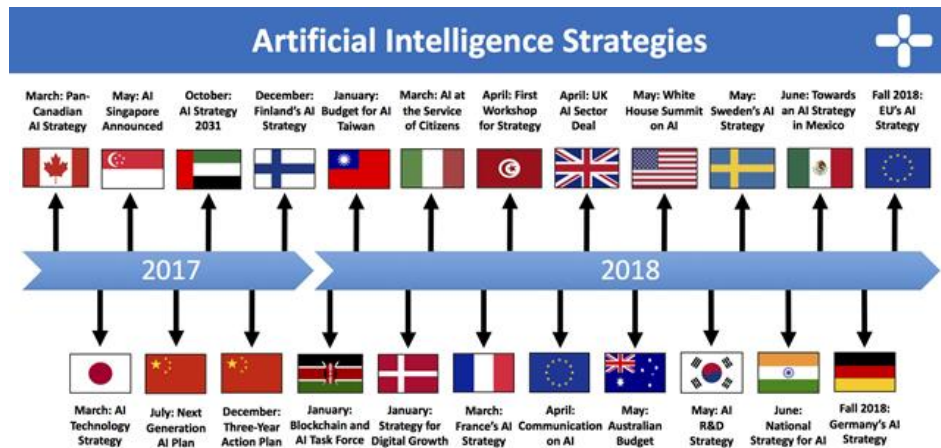


Figure 1. National artificial intelligence strategies classified by year of implementation.
Source: 'An Overview of National AI Strategies' - Politics + AI

Along these lines, on 25 April 2018, the European Commission approved a communication that details the planned actions for a European artificial intelligence strategy, through a coordinated plan with Member States to foster the development and use of artificial intelligence in Europe. With this plan, which was presented on 7 December 2018⁵, the European Commission set the objective to mobilise €20 billion of public and private investment for the 2018-2020 period.

Within this framework, the Commission has requested Member States to adopt their respective national artificial intelligence strategies, defined in mid-2019, and that the strategies focus on four key areas: increase investment, make more data available, foster talent and ensure trust in artificial intelligence.

2.2 Artificial intelligence around the world

The United States (US) is the clear leader of the artificial intelligence market. It evidently has the strongest artificial intelligence ecosystem in terms of funding, number of companies and global reach. A total of 40% of AI companies are located in America, although the figure would be higher if we took into account that the most relevant AI companies have a sales office or headquarters in the United States, while their main technology teams are based in another place, such as Poland, Israel or France. America's leadership is the result of a mature, well-funded and prosperous digital ecosystem, as shown

⁵ http://europa.eu/rapid/press-release_IP-18-6689_es.htm.

by Silicon Valley and the metropolitan areas of New York and Boston. Over 16 governmental agencies give financial and political support to AI companies (including the DARPA, the CIA and the NSA).

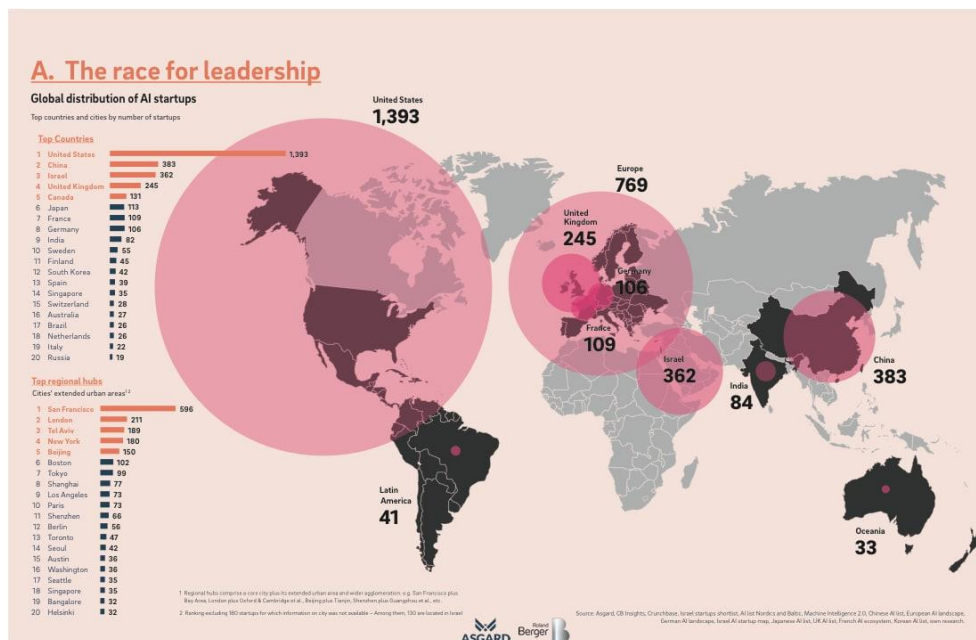


Figure 2. Global distribution of AI start-ups

Source: Asgard & Roland Berger

The United States also has renowned universities (Stanford and MIT), in addition to large corporations with powerful research capacity (Google and DeepMind, Microsoft, Facebook, Amazon, Apple and IBM). The United States is a model to follow as regards how a technological industry can grow strongly when there is a convergence of governmental stimulation, applied research carried out by universities and corporations, entrepreneurship, private funding and a prosperous market. It is worth mentioning that the migration policies of the current US government are resulting in a certain human capital flight in the artificial intelligence research sector towards other ecosystems. Canada is particularly attractive.

According to the analysis of existing data, China is in second position. Approximately 11% of AI companies are located in the country, which has publicly announced its intention to become the world leader in artificial intelligence by 2030 (Alibaba, Baidu, Huawei and ZTE are examples of huge Chinese corporations). Artificial intelligence forms part of its ambitious five-year development plan and the government is going to invest billions of Chinese yuan in research centres in Beijing and Shenzhen. The initial market is well-funded, and valuations are even higher than in Silicon Valley. China shows the highest growth in the number of scholarly articles published and it has launched numerous AI-related initiatives, demonstrating that with governmental support, adequate funding and a clear strategy, a country can become an influential AI player in only a few years.

Israel is a leader in technology, ranking third in AI solutions. With only 8.5 million citizens, it has a market share of 11%, the same as China and has 40 times more AI companies per capita than the market leader, United States, which places Israel in the front line of artificial intelligence at an international level. One of the reasons for this leadership is the close connection between the defence industry and the digital sector, although Israel is well-known for its long history of tech companies, not only for artificial intelligence. There are excellent universities (Technion, Bar-Illan, Ben-Gurion and Jerusalem) and a strong business ecosystem in Tel-Aviv.

The United Kingdom has a market share of 7%, which places the country at the forefront of artificial intelligence in Europe. It is well-positioned at an international level as regards obtaining and attracting funding, talent and research. London is a global financial hub; therefore, funding of AI companies in the United Kingdom is significantly higher than in other European countries. Furthermore, for years the UK government has been creating a powerful entrepreneurship and investment environment focused on this sector, and it also has excellent universities (such as Oxford and Cambridge).

Canada is another leader in the field of artificial intelligence and is currently number five on the Global AI country ranking. Although Canada promotes entrepreneurship-friendly politics, its market share is surprisingly similar to that of other countries (3.8%), Japan (3.1%), France (3.1%) and Germany (3%). All are strong economies with a large domestic market. However, compared by size of economy, France and Germany's efforts to develop AI industry leadership capacity are small in contrast to the United States, China, and Israel. The same happens in many other countries such as India (9), Spain (13), Brazil (17) and Russia (20). Most of these countries have a huge deficiency of AI companies and unless they invest considerably more effort and capital to reduce their deficiency in artificial intelligence, they will have to depend on AI solutions from China, the United States and Israel. It is worth noting that the government of Catalonia, through ACCIÓ, provides an opportunity to establish international relationships with these ecosystems by way of its network of 40 offices aimed towards encouraging internationalisation, technological cooperation and innovation.

At the end of 2018 Europa presented its AI4EU project⁶ in Barcelona. AI4EU is the European Union's benchmark AI project and is the European footprint within the global context of artificial intelligence, which seeks to develop a European AI ecosystem, bringing together the knowledge, algorithms, tools and resources available and making it a convincing solution for users. Catalonia's participation in this project is headed by the BSC-CNC, the UPC and ATOS, which are joined by other relevant initiatives promoted by the European AI community, such as CLAIRE⁷ and ELLIS,⁸ that aim to promote a network of AI labs in Europe.

⁶ <https://www.ai4eu.eu>

⁷ <https://claire-ai.org>

⁸ <https://ellis.eu>

2.3 Sectors impacted by artificial intelligence

Artificial intelligence is a technology that offers great potential and financial prospects in all markets. According to a study by PwC,⁹ the financial impact of artificial intelligence on the total global GDP will come from four sources: increased productivity from business automating processes (including use of robots and autonomous vehicles); increased productivity due to businesses augmenting their existing work force with AI technologies (assisted and augmented intelligence); the previous factors will result in saving time and cutting production costs; increased consumer demand resulting from the availability of personalised and/or higher-quality AI-enhanced products and services.

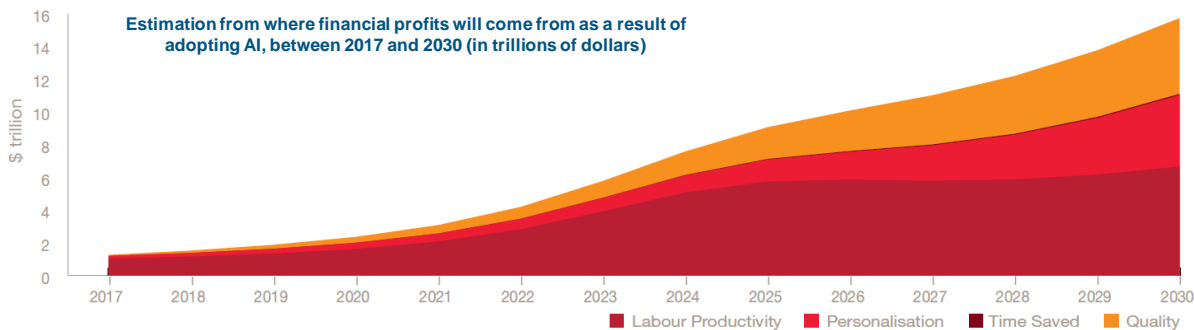


Figure 3. Where financial profit comes from as a result of the adoption of artificial intelligence.

Source: Sizing the prize. What is the real value of AI for your business and how can you capitalize – PwC

As mentioned above, artificial intelligence is a technology that stands out for its cross-cutting impact; therefore, its uptake will gradually increase in many different sectors, including the following:

- ICT and cybersecurity
- Citizen defence and safety
- Healthcare
- Tourism and leisure
- Industry 4.0
- Automotive industry
- Banking and finance
- Retail

The figure below shows some of the ways that artificial intelligence will impact these sectors at short, medium and long term, according to the technology report 'Artificial Intelligence in Catalonia', drawn up by the government of Catalonia.

⁹ 'Sizing the prize. What is the real value of AI for your business and how can you capitalize', drawn up by PwC

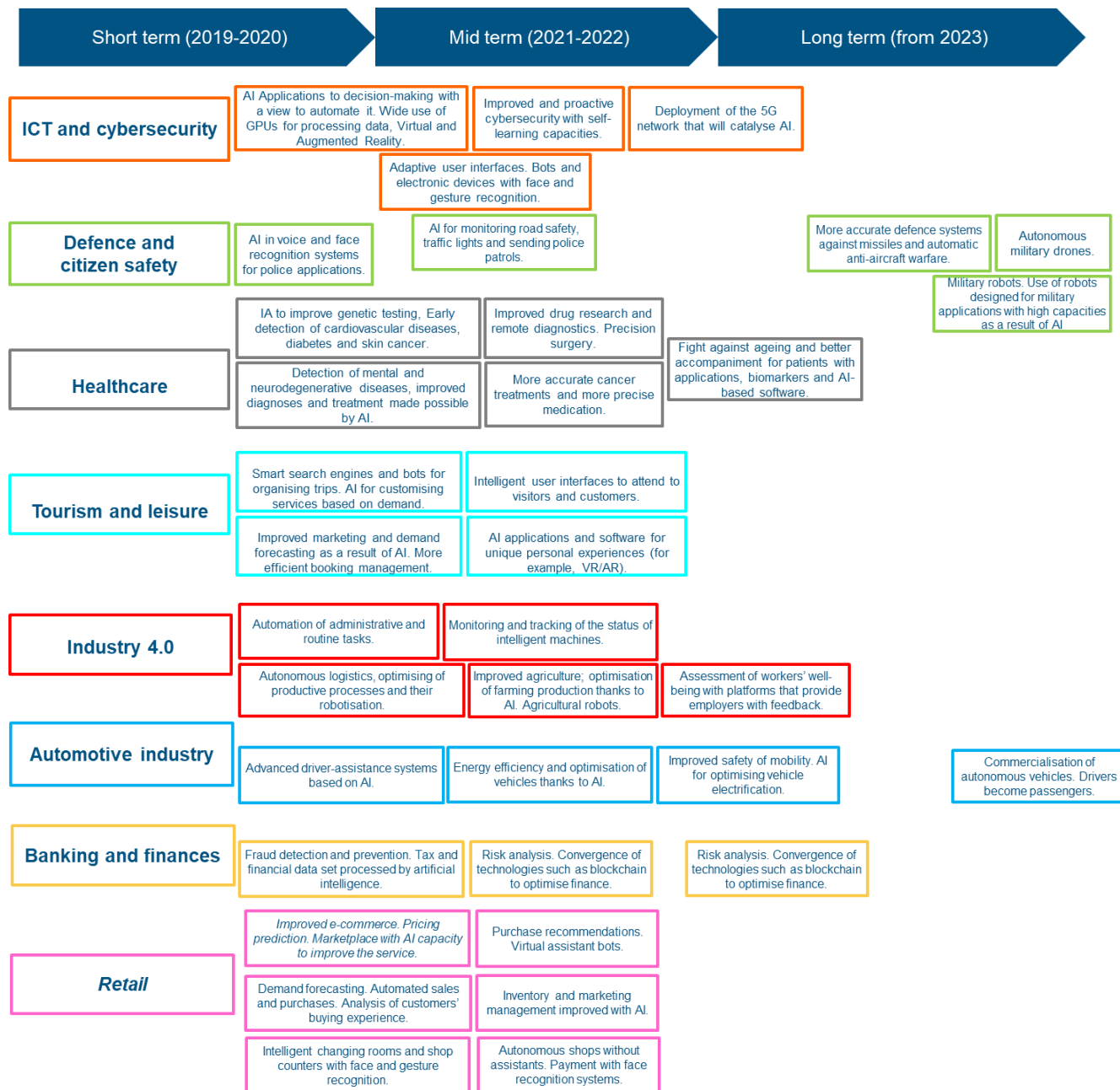


Figure 4. Recent and prospective applications classified by sectors' demands.
Source: technology report 'Artificial Intelligence in Catalonia' – Government of Catalonia

3. Available capabilities in Catalonia

Catalonia has the capabilities and potentialities to position the country in a privileged position to lead the development and adoption of artificial intelligence in Southern Europe and convert it into a global technological pole of attraction in artificial intelligence. To understand what this position represents from an international perspective, it is necessary to bear in mind the different capabilities inherent in Catalonia, such as its knowledge ecosystem, ecosystem of technology companies and its scientific and technological infrastructure.

The following sections describe each one of the capabilities that make Catalonia into an ideal place for developing, testing and deploying artificial intelligence.

3.1 Knowledge ecosystem

Catalonia's top vector in artificial intelligence is related to the promotion of knowledge. The region has a knowledge ecosystem that would enable it to head the deployment of artificial intelligence with guaranteed success. Its universities, research teams and departments, applied research centres, technology centres and associations demonstrate Catalonia's existing potential.

3.1.1 Universities

The Catalan university system is made up of 12 universities: seven are public, four are private and one is a virtual university. A total of 26,300 lecturers give classes to over 237,000 students, who are offered about 1,300 university degrees, divided into bachelor's, master's and doctoral degrees.



Figure 5. Catalan university map
Source: Government of Catalonia

These bodies offer specialised training. Indeed, they have brought together their knowledge, driven technology creation and worked on research and technology transfer projects related to artificial intelligence.

By way of illustration, the figure below shows the main research centres and groups of the different Catalan universities that develop artificial intelligence or work with AI intensively.



Figure 6. Groups or research centres that develop or work with artificial intelligence.
Source: technology report 'Artificial Intelligence in Catalonia' – Government of Catalonia

The annexe of this document contains a detailed explanation of the involvement of Catalan universities in AI development in the region.

3.1.2 Research and innovation centres

The Catalan research and innovation system is currently made up of internationally renowned research and technology centres. These centres are structured into two interrelated networks: firstly, the CERCA¹⁰ network, which groups together Catalan research centres and is managed by the CERCA Institute, using its own means and the technical services of Catalan government bodies and, secondly, the TECNIO¹¹ network, focused on the transfer of technology, which joins research groups, CERCA and

¹⁰ <http://cerca.cat/>

¹¹ <http://www.accio.gencat.cat/ca/serveis/innovacio/tecnologia-per-a-empresa/tecnio/>

CSIC centres, universities, technology centres, hospital institutes, engineering firms and technology-based companies, in this case managed by ACCIÓ, the Agency for Business Competitiveness.

By way of illustration, the figure below shows the main research and technology centres of the Catalan knowledge ecosystem that work with artificial intelligence.



Figure 7. Technology and research centres that work with artificial intelligence in Catalonia.
Source: technology report 'Artificial Intelligence in Catalonia' – Government of Catalonia

Annexe II of this document contains detailed information about the work carried out by each one of these centres related to AI development.

3.1.3 Participation in the H2020 Framework Programme

Catalonia is the region of Spain that has received the highest number of grants from the European research and innovation funding programme, Horizon 2020. According to information obtained on 30 April 2019 by the CDTI (Centre for the Development of Industrial Technology), during the 2014-2019 period Catalan entities received a total of €1,013,004,988 to subsidise Horizon 2020 projects. This figure represents 2.71% of the programme's implemented budget and 29.23% of the total subsidy received by Spanish entities.

As regards information and communications technology (ICT), Catalan entities have also played a significant role and have received a total subsidy of €85,961,783, which represents 2.87% of the total implemented budget and 28.84% of the funds awarded to Spain.

The 10 Catalan entities that have received funding for information and communications technologies are the following (listed in order according to the size of the grant, starting with the highest amount):

- Barcelona Supercomputing Center (MareNostrum)
- Polytechnic University of Catalonia (UPC)
- Pompeu Fabra University (UPF)
- Eurecat Foundation

- Semidynamics Technology Services SL
- i2CAT Foundation
- Catalan Agency for Healthcare Quality and Evaluation (AQUAS)
- Institute of Photonic Sciences (ICFO)
- Foundation for the Open University of Catalonia (UOC)
- Rovira i Virgili University (URV)

Further information about Catalonia's participation in the H2020 programme is available on the RIS3-MCAT¹² platform, developed by the government of Catalonia. Visitors are offered an interactive view of the activities of Catalan entities related to science and innovation projects supported by European funds and the dynamic evolution of the collaboration networks between each entity.

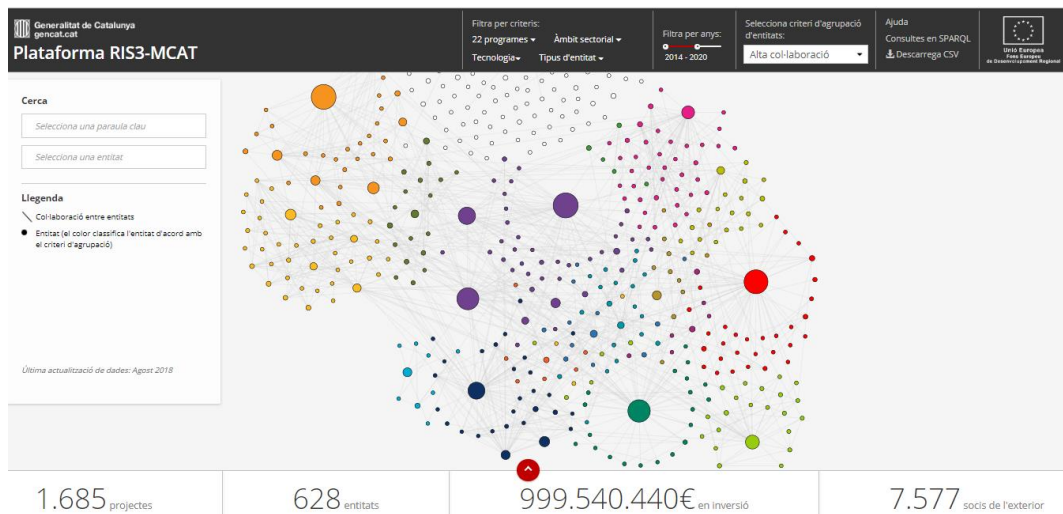


Figure 8. The RIS3-MCAT Platform
Source: Government of Catalonia

3.1.4 Catalan Association for Artificial Intelligence

Professor Ramon López de Mántaras brought artificial intelligence to Catalonia in the 1980s. It quickly propagated and spread all over the region, resulting in the consolidation of a tight-knit scientific community that revolved around artificial intelligence. In 1994, the Catalan Association for Artificial Intelligence (ACIA)¹³ was definitively established.

The ACIA is a non-profit association created with the purpose of promoting artificial intelligence in the Catalan society. Its main goal is to support communication between the professionals and

¹² <http://unics.cloud/ris3/mcat>

¹³ <https://www.acia.cat>

organisations that participate in artificial intelligence and promote social, cultural, scientific economic and governmental awareness of artificial intelligence.

The ACIA was created 25 years ago with the aim of being a meeting point for all researchers who were already working in this new and unknown field. The entity was formed on 28 March 1994 and the Articles of Association were approved. During the summer of that year, the first edition of the Association's magazine was published (the ACIA Bulletin, later called NODES¹⁴) and the entity began to organise the Young Researchers' Meetings that would later become the International Conference of the ACIA.

Nowadays, the ACIA brings together the greater part of this scientific community, as well as former students and professionals of the sector. At present, the Association has over 220 individual and institutional members, it has published more than 60 magazines and books, and has organised 22 international conferences. Although the association belongs to a small region, since 1995, it has been a member of the European Association for Artificial Intelligence, now known as EurAI, and since 1998 it has organised its annual international conference, the CCIA¹⁵, yet again acting as a pioneer, with some of the proceedings published by one of the most prestigious publishing houses, IOS Press. The ACIA organises and participates in dissemination activities including the YoMo, the celebration of the 60th anniversary of artificial intelligence and the Association's 25th anniversary, among others. On 8 March 2019, the ACIA created a working group aimed towards narrowing the gender gap in the AI sector (donesIAcat). It also sponsors conferences, awards prizes to doctoral theses and master's dissertations, and grants to attend conferences.

As regards international scientific leadership, the fact that the ACIA has 10 EurAI Fellows is highly relevant. The EurAI Fellows programme dates back to 1999 and is a very selective programme that has honoured less than 3% of its members; Spain has 16 EurAI Fellows, of which 10 are from ACAI, and only France, Germany, the United Kingdom and Italy have more fellowships than Catalonia.

3.2 Ecosystem of technology companies

3.2.1 The ICT industry in Catalonia

ICT is one of Catalonia's most dynamic sectors. It has one of the most important industrial clusters in Europe, with a group of highly competitive software developers, which provides the region with a high capacity to create innovative solutions adapted to the reality of each vertical of the industry or services, in addition to the fact that these solutions are validated and even co-created by future users before they are launched onto the market.

In 2018, the Catalan ICT industry was made up of a total of 15,757 companies, a figure that had grown by 4.5% in respect to 2017 and increased by a remarkable 27% since 2013. Between them, they create

¹⁴ <https://nodes.acia.cat>

¹⁵ <https://agenda.uib.es/29216/detail/ccia2019.html>

106,900 jobs (2018) and have a turnover of €16,667 million (2016), a figure that has increased by 14% in the last two years.



Figure 9. Main figures of the ICT industry in Catalonia (February 2019)
Source: sectoral snapshot 'The ICT Industry in Catalonia – Government of Catalonia

Barcelona is the top-ranking start-up hub in southern Europe in terms of number of businesses, and fifth in Europe overall after London, Berlin, Paris and Amsterdam, according to the ranking in Europe's biggest start-up hubs in 2017 published by EU-Startups.¹⁶

The Barcelona & Catalonia Startup Hub¹⁷, the most complete directory of start-ups in Catalonia, has identified over 1,300 start-ups that employ nearly 14,000 people. The diagram below includes the main facts associated to the Catalan start-up ecosystem.



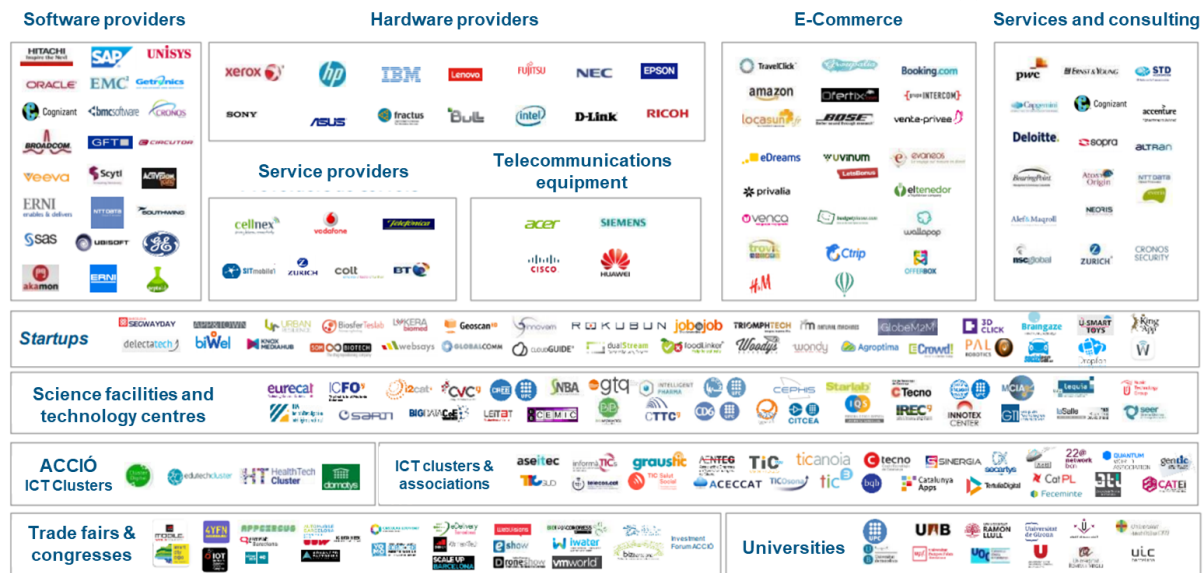
Figure 10. Catalan start-ups expressed in figures (November 2018)
Source: Analysis of the Barcelona & Catalonia Startup Hub, 2018 – Government of Catalonia

¹⁶ <https://www.eu-startups.com/2018/11/top-15-europes-biggest-startup-hubs-in-2018/>

¹⁷ <http://startupshub.catalonia.com/>

In fact, Barcelona is considered the third-favourite start-up hub by 20% of European founders, who would choose the city to establish their emerging company, after London and Berlin, as ranked by the Startup Heatmap Europe 2018¹⁸.

Therefore, the ecosystem in the ICT industry is the result of an unprecedented capacity to bring enterprises together and it stands among Europe's most competitive and dynamic hubs. By way of illustration, the following picture shows a map of the main companies and players in the Catalan ICT industry.



Note: These brands have been used for informational purposes. The brands referred to in this report belong to their respective owners and under no circumstances belong to ACCIÓ. This is a partial and illustrative representation of the companies that form part of the ICT ecosystem in Catalonia, but there could be other companies that have not been included in the study.

Figure 11. The ICT ecosystem in Catalonia (February 2018).

Source: Sectoral snapshot 'The ICT Industry in Catalonia – Government of Catalonia

3.2.2 Catalan digital hub, an attractive region for foreign investment

The *fDi Magazine* published by the Financial Times has recognised Catalonia as the most attractive region in southern Europe in terms of foreign investment for 2018 and 2019.¹⁹ This is one of the most prestigious international rankings used by multinationals to study future business investment projects.

It is worth noting the investments made by multinationals and start-ups of the ICT industry (28.6% of the total in 2017), a sector that creates wealth and qualified jobs with a strong growth potential, which demonstrates the pulling effect of the technology sector for the Catalan economy.

As a whole, investors perceive Catalonia and Barcelona as a very attractive place to invest. The region is rated globally at 3.7, on a scale of 1 to 5, with 5 being 'very attractive to invest'. Asian companies are

¹⁸ <https://www.startupheatmap.eu/>

¹⁹ http://catalonia.com/newsletter_news/news/2018/financial-times-recognises-catalonia.jsp

those that best rated the region, with 3.73 points, followed by European and American companies, with 3.70 and 3.65 points respectively.

A significant number of large multinationals have chosen Catalonia, particularly the Barcelona metropolitan area, to establish their ICT centres: technology-based centres of excellence and digital hubs that provide a service at an international level.

In the last three years, the region has attracted centres belonging to Zurich, Axa, Visa, Roche, Allianz, Asics, Lidl, Media Mark and Nestlé, as well as centres owned by technology companies, including Oracle, Cisco, Facebook, Amazon, Microsoft, Satellogic, Siemens, Deloitte, Moodle, Gartner, Igg, Zoughtworks, GFT and NTT Data, among others.

These new centres are added to a long list of multinational ICT centres located in Catalonia, which have already positioned Barcelona and Catalonia as one of the world's most important digital connection centres, as shown by this figure:



Figure 12. Multinational companies with digital hubs in Catalonia (February 2019)
Source: sectoral snapshot 'The ICT Industry in Catalonia – Government of Catalonia

3.2.3 The AI sector in Catalonia

In June 2019, the government of Catalonia published a technology report, 'Artificial Intelligence in Catalonia', which defines the ecosystem of companies, universities, research and innovation centres that support the AI sector in Catalonia.

According to the study, there are 179 companies in Catalonia operating in the field of artificial intelligence. These enterprises currently employ 8,483 people and have a combined turnover of €1.336 billion for activities linked to artificial intelligence.

The sector is mostly made up of businesses formed by entrepreneurs, of which 63% are start-ups. According to their segment of the value chain, they are distributed as follows:

- Algorithm developers (19)
- Consultancy firms (19)
- Software or device developers (134)
- Service providers (7)

By way of illustration, the following picture shows the map of the companies and players in the Catalan AI ecosystem.



Figure 13. Companies and agents of the AI ecosystem in Catalonia (June 2019)
 Source: technology report 'Artificial Intelligence in Catalonia' – Government of Catalonia

3.3 Scientific and technology infrastructures

3.3.1 Scientific infrastructures

Catalonia has powerful and unique scientific infrastructures at the disposal of both the Spanish and foreign scientific, technological and industrial community. Below are the most strategic scientific infrastructures for developing artificial intelligence in Catalonia.

- **Barcelona Supercomputing Center (BSC-CNS)**

Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) is a scientific facility that offers high performance computing (HPC) services and manages MareNostrum, one of the most powerful supercomputers in Europe, located in the Torre Girona chapel.

BSC-CNS is at the service of the international scientific community and the industries that require HPC services. Its multidisciplinary research team and computational facilities –including MareNostrum– convert BSC-CNS into an international centre of excellence in e-Science.

Since its creation in 2005, BSC-CNS has played an active role in fostering HPC in Catalonia and Spain as an essential tool for international competitiveness in science and engineering. The centre manages the Spanish Supercomputing Network (RES) and is a hosting member of the Partnership for Advanced Computing in Europe (PRACE). The centre actively participates in the main European HPC initiatives, in close cooperation with other European supercomputing centres and is one of the institutions most actively involved in setting the EuroHPC joint undertakings into motion.

On 7 June 2019, the European Commission announced that it would invest €100 million in MareNostrum 5²⁰ a pre-exascale machine with peak power 17 times higher than the current supercomputer, MareNostrum 4, and 10,000 times higher than the supercomputer that began the saga in 2004, MareNostrum 1. The decision guarantees Barcelona a leading position in the future map of supercomputing in Europe.

- **L'Anella Científica (Scientific Ring)**

The *Anella Científica* is an academic and research telecommunications network that connects about 80 institutions related to research and innovation, which enables users to exchange and process big data in a secure environment. Besides connectivity, with different speeds and modalities, the member institutions are offered numerous additional services.

The *Anella* has a core with a link at 100 Gbps between its core nodes (Campus Nord and Itconic) that finish in 5 ports, of which one is for the CATNIX neutral Internet exchange point. Each node is connected at 10 Gbps. The *Consorci de Serveis Universitaris de Catalunya* – CSUC (Consortium of University Services of Catalonia) directly manages the optical technology, switches and routers that enable interconnection between the nodes and connected institutions with a fully dedicated architecture as regards fibres and systems.

The *Anella Científica* is connected to the Spanish academic network, RedIRIS, and via this network it is connected to the other academic networks in Europe and the rest of the world. It is also connected to the Catalonia Neutral Internet Exchange Point (CATNIX), which provides commercial suppliers with excellent connectivity.

3.3.2 Technology infrastructures

Thanks to the efforts of public and private entities, Catalonia has first-class technology infrastructures too, which are already operating throughout the entire region. The cross-cutting nature of artificial intelligence fits in perfectly with the strategy to add functionalities to these infrastructures so they may act as a whole to support the fields and sectors where this technology is applied. Described below are the most strategic technology infrastructures for the development of artificial intelligence in Catalonia.

²⁰ <https://ja.cat/IRpd7>

- **Public network of optical fibre throughout the territory**

The government of Catalonia is promoting the deployment of the public network of optical fibre throughout the entire region, so as to provide its own network for corporate connectivity and make use of the surplus network to offer services to telecommunications operators with optimum conditions of competitiveness, thus promoting the development of advanced digital technologies. The network currently encompasses over 4,500 km that can provide an effective point of presence in 254 Catalan municipalities.

The framework of the National Pact for the Digital Society includes a plan to roll out the public network of optical fibre to connect all the capitals of administrative divisions by 2020, so as to provide an effective point of presence in all Catalan municipalities and areas of economic activity by 2023. The plan is to provide 8,500 km of optical fibre open to telecommunications operators.

In this way, the offer of dark fibre wholesale services and active circuits for deploying the services provided by telecommunications operators in geographical areas, traditionally disadvantaged by the digital fracture, seeks to ensure that the new technology is not only born and rolled out in urban areas concentrated near Barcelona, but to also deploy it in rural environments away from the metropolitan area.

The main objective is to convert Catalonia into a connected territory that makes use of technology and digital information and uptakes new technological proposals for mobile devices – such as 5G technology – to lead the innovation of public services, accelerate economic growth and promote a more intelligent, sustainable and integrated society.

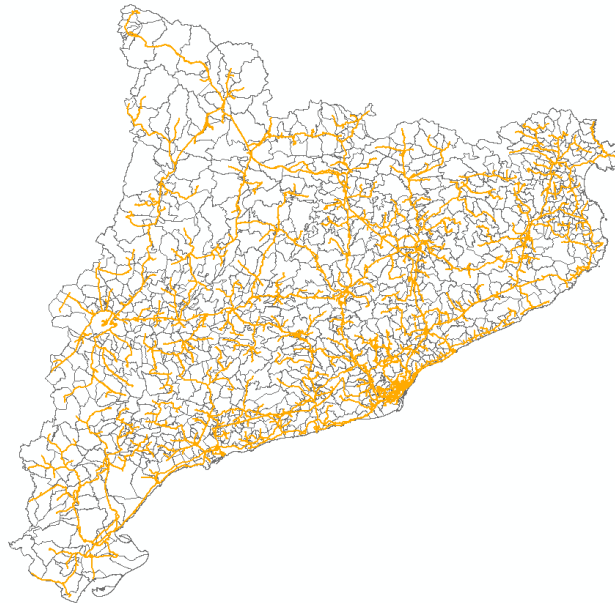


Figure 14. The public fibre optic network in Catalonia (2023).
Source: Government of Catalonia

- Data Processing Centres

The government of Catalonia is the principal consumer of the country's computer systems; as a result, the tender of the new ICT model put out by the government in 2012, which combined all the government's Data Processing Centre (DPC) infrastructure services, meant that the best DPC infrastructure in the country was deployed in Catalonia.

Furthermore, international DPC infrastructure and cloud-based platforms belonging to companies such as IBM, HP, T-Systems and Mediacloud were implemented in Catalonia when the companies that had been awarded the DPC infrastructure services executed their industrial plans. These were added to the first-rate DPC infrastructures that had previously existed in the country.

Consequently, in Barcelona and surrounding areas there are three main zones with a concentration of top-notch DPC infrastructure (Parc de l'Alba, Zona Franca/are@38 and 22@Barcelona) which positions the region as one of the most important concentrations of Data Processing Centres in Europe. These are infrastructures that are at the service of the public and private sector so it may develop digital transformation projects and programmes that require processing big data, thus establishing a fundamental asset for developing artificial intelligence in Catalonia.



Figure 15. Area of the main Data Processing Centres in Catalonia
Source: Government of Catalonia

3.4 SWOT analysis of Catalonia's artificial intelligence ecosystem

Having identified Catalonia's AI ecosystem and bearing in mind the climate of artificial intelligence development around the world, a SWOT analysis was conducted to know the strengths, weaknesses, opportunities and threats of Catalonia's AI ecosystem. The purpose of the analysis was to strategically assess the current situation and set achievable objectives that promote development. The results of the SWOT analysis are shown below:



Figure 16. SWOT analysis of the Catalan AI ecosystem
Source: authors' own compilation

4. CATALONIA.AI: the Catalan artificial intelligence strategy

The government has put priority on promoting artificial intelligence and aims to support the deployment of AI technology, thus making Catalonia a renowned pole of attraction for research, innovation and talent, companies and investors in the field of artificial intelligence.

Through this objective, the government is promoting artificial intelligence in Catalonia. Under the name of CATALONIA.AI, it will deploy a programme of specific actions to strengthen Catalonia's AI ecosystem and lead knowledge creation, social and business application and create solutions based on artificial intelligence aimed towards fostering economic growth and improving people's lives.

Catalonia's Artificial Intelligence Strategy is coordinated by the Secretariat for Digital Policy of the Ministry for Digital Policy and Public Administration of the government of Catalonia, with the direct collaboration of the Secretariat of Business and Competitiveness and the Secretariat of Universities and Research of the Ministry of Business and Knowledge, and the participation of the remaining ministries.

4.1 Objectives and values

CATALONIA.AI is fully aligned with the European objectives associated to the deployment of artificial intelligence and it will consequently promote all the capabilities of the Catalan ecosystem referred to in the previous section, of public or private origin, cooperation, innovation and internationalisation, so as to establish its leadership in southern Europe and become a top player in the global environment.

The goals associated to the deployment of the Strategy are listed below:

- Boost the AI ecosystem in Catalonia
- Position Catalonia as one of the driving forces of artificial intelligence in Europe
- Convert Catalonia, particularly Barcelona, into a global AI hub
- Create, retain and attract specialised talent in artificial intelligence in Catalonia
- Boost research and innovation in artificial intelligence in Catalonia
- Create, maintain and govern an easily accessible open data repository
- Encourage companies and institutions to adopt artificial intelligence
- Train professionals and citizens to use artificial intelligence
- Explain to citizens that artificial intelligence will have a positive impact on their well-being
- Promote a sustainable, comprehensive, secure and fair development of artificial intelligence in Catalonia

CATALONIA.AI assumes the values of the Barcelona Declaration for the Proper Development and Usage of Artificial Intelligence in Europe²¹ and fully agrees with the recommendations on artificial intelligence provided by the High-Level Experts of the European Commission. Said recommendations are contained in the Ethics Guidelines for Trustworthy AI²² and the Montreal Declaration for a Responsible Development of Artificial Intelligence,²³ which place people, whether they are developers or users, in the centre. Artificial intelligence needs to be able to increase people's capabilities, not replace their intelligence, and has to help increase individual and collective well-being.

In this regard, CATALONIA.AI will promote the development of artificial intelligence in such a way that

- It benefits people, societies and the planet
- It is plural, diverse and comprehensive in its sources of knowledge
- It is secure and trustworthy throughout its life cycle
- It is applied sensibly
- It is responsible for its actions
- It is transparent in its decisions
- It respects privacy
- It complies with civil, legal and democratic systems
- It is aligned with human values
- It focuses on people
- It is controlled by people

4.2 Strategic pivotal elements of the action plan

CATALONIA.AI will deploy a multi-sectoral, cross-cutting plan that focuses on people; prioritises sectors such as healthcare, mobility, sustainability, productive economy, the agri-food sector and public services; and will be established in an action plan that revolves around the pivotal elements listed below:

- **Ecosystem:** promote a cross-cutting governance model that supports the development of a coordinated ecosystem of artificial intelligence connected to the rest of the world.
- **Research and innovation:** boost research and innovation by applying specific instruments and establishing synergies between public authorities, specialised research and innovation centres and organisations that use artificial intelligence intensively.
- **Talent:** create, attract and retain specialised talent that fosters the development of artificial intelligence solutions and transfer of knowledge to society, while training citizens and professionals of other sectors to be ready for its impact.
- **Infrastructure and data:** have the necessary infrastructures for the development of artificial intelligence and provide secure access to public and private data.

²¹ https://www.bdebate.org/sites/default/files/barcelona-declaration_v7-1-eng.pdf

²² https://www.huntonprivacyblog.com/?attachment_id=17432

²³ <https://www.declarationmontreal-iaresponsable.com/>

- **Adoption of artificial intelligence:** promote the incorporation of artificial intelligence to drive innovation in Public Administration and strategic sectors, including agri-food, healthcare and well-being, the environment, mobility, tourism, culture and industry.
- **Ethics and society:** promote the development of ethical artificial intelligence that respects applicable legislation, is compatible with our social and cultural norms and focuses on people.

The lines of action and initiatives associated to each one of the six pivotal elements are shown below:

4.2.1 Ecosystem

One of the key elements for AI development is having a strong and coordinated ecosystem where the different agents are connected to enable them to create synergies, complement each other when tackling large projects, promote existing initiatives or create new ones.

This ecosystem is made up of universities, research and innovation centres, public bodies, companies, investors and support institutions. Its governance, and the relationship between each other and other existing ecosystems have to make Catalonia into a renowned pole of attraction in artificial intelligence.

4.2.1.1 Creation of a cross-cutting and open governance structure

One of the priorities of the Catalan strategy is to create an organisation whose operations will focus on heading the promotion of the Catalan AI ecosystem. This structure will be responsible for governance of the Catalan strategy and, among other matters, this will involve managing the resources, infrastructure, talent, opportunities, alliances and ensure that the established plan and strategy is accomplished with transparency, equality and ethics.

CATALONIA.AI has to be the front door for AI research and innovation projects and initiatives, as well as associated solutions and developments. CATALONIA.AI has to be the frame of reference of cutting-edge technology and must represent the entire community of people who create and use knowledge, with the ability to establish connections. It should also be able to receive local and international funding, align collaborations between public and private stakeholders and establish cooperation between leading international entities in this field.

In this regard, an open, plural, transparent and multidisciplinary community will be created under the umbrella of the Strategy in progress, known as CATALONIA.AI ALLIANCE. This alliance will enable players to share knowledge, create and attract ideas and challenges, carry out research, exchange experiences in a participative and coordinated manner with other communities involved in advanced digital technologies, with the capacity to receive funding from Catalonia, Spain and abroad, as well as generate collaboration and knowledge transfer projects.

The AI ecosystem is structured around three main areas: the first involves creating knowledge and research of excellence, the second is associated to transferring technology to the market and creating impact and the third focuses on creating the ecosystem that will support the creation and growth of start-ups and new solutions.

4.2.1.2 Catalonia as an international AI pole of attraction

One of the basic objectives of the CATALONIA.AI Strategy will be to boost international cooperation by establishing collaboration agreements with other ecosystems, associations, companies, universities, and international research and innovation centres of excellence, thus making it possible to create and develop projects, create joint programmes and benefit from international programmes such as Horizon Europe²⁴ or the new programme, Digital Europe,²⁵ which will drive Europe's future in the next few years, among many other existing possibilities.

Barcelona's position as a global leader in digital technologies, particularly because it is the world capital of mobile technology (Mobile World Capital²⁶) and due to its first-class international congresses, such as the Mobile World Congress (MWC Barcelona²⁷), Smart City Expo World Congress²⁸ and IoT Solutions World Congress,²⁹ together with the existence of infrastructure and first-class research and innovation centres (including the Barcelona Supercomputing Center), are all elements of maximum visibility that will draw companies, research and innovation centres that are at the forefront of artificial intelligence, so as to establish operational hubs or create joint projects, thus significantly increasing the quality of projects produced by the ecosystem as a whole and collaborations with the innovative, entrepreneurial and investigational network that previously existed in our country.

Within this context, it would be worthwhile to create an advanced catalogue of technologies, CATALONIA.AI TECHNOLOGY, which would include technology-based companies, research and innovation centres, knowledge-creating companies and success stories of our ecosystem, thus boosting Catalonia's presence in international events and providing leading international business decision-makers and investors with a well-structured and attractive critical mass and showing how technological development in artificial development impacts our society and people's well-being.

In a similar way as the other major events related to advanced digital technologies held in Barcelona every year, it will be necessary to study the possibility of bringing close or granting an international AI event to Catalonia. In addition, work will be accrued out to promote the development of international events related to artificial intelligence in line with those that already exist, such as the AI & Cognitive Systems Forum³⁰ that forms part of the IoT Solutions World Congress, the International Congress of the Catalan Association of Artificial Intelligence or the BigData Congress,³¹ organised by Eurecat.

As regards the CATALONIA.AI Strategy and the associated international component, a network of international ambassadors and AI project hunters will be created, as well as an advisory council. Both will be made up of renowned leaders from the world of research and innovation in artificial intelligence, researchers, advisors and business managers with proven experience in international

²⁴ https://ec.europa.eu/info/designing-next-research-and-innovation-framework-programme/what-shapes-next-framework-programme_en

²⁵ <https://ec.europa.eu/digital-single-market/en/news/commission-welcomes-agreement-digital-europe-programme-2021-2027>

²⁶ <https://mobileworldcapital.com>

²⁷ <https://www.mwcbarcelona.com>

²⁸ <http://www.smartcityexpo.com>

²⁹ <https://www.iotsworldcongress.com>

³⁰ <https://www.iotsworldcongress.com/congress/tracks-themes/ai-cognitive-systems-forum-2/>

³¹ <https://bigdatacongress.barcelona/>

projects and markets, either from Catalonia or outside, or entities, companies or institutions with which collaboration is already underway or could be of interest.

Likewise, as part of the internationalisation strategy, in addition to the presence of CATALONIA.AI in international events, government delegations abroad and the International Network of Trade and Investment Offices will collaborate in order to ensure contact with people and entities of the highest level and promote the creation of opportunities and projects for Catalan entities and companies that work in this field.

4.2.1.3 An attractive country for national and international AI investment

In recent years the presence of international companies and investors involved in advanced digital technologies has increased exponentially in our region. In this regard, the decision taken by different multinationals to establish their digital operations in Catalonia must not be ignored by the international ecosystem, and it is therefore necessary to make it known and consequently take advantage of the opportunities it offers. In this regard, both CATALONIA.AI TECHNOLOGY, mentioned above, and the direct collaboration of the Agency for Business Competitiveness (ACCIÓ), in charge of the foreign investment programme, Invest in Catalonia,³² have to be able to boost the knowledge transfer processes and improve the connection of technology created in the region with national and international economic, social and business sectors with the capacity to invest in individual or cooperation AI-based projects. This capacity must not only translate into having favourable locations or technologies, noteworthy research and innovation centres, or companies with products under development, but must also imply setting up favourable tax measures and encourage digitisation between companies as a fundamental element of present and future competitiveness.

The CATALONIA.AI Strategy includes promoting different actions geared towards encouraging cooperative or financial investment, especially in technology-based companies, research and innovation centres and groups. This will be achieved by setting up tax incentives or loans with favourable conditions, for example, those linked to connection programmes with the European Investment Bank or the European Commission's Investment Plan for Europe. Likewise, following other experiences in our region, priority will be given to holding Investment Forums or Investment Readiness Series as part of the activities carried out by the Barcelona & Catalonia Startup Hub, the previously mentioned congresses or others associated to AI sectoral applications. An application will also be created, CATALONIA.AI INVESTMENT, which will include information about investors, professionals and companies that wish to invest in digital technologies, especially in relation to artificial intelligence. This application will enable potential investors or licensees to be in direct contact with technologies under development and, furthermore, specific actions will be carried out to attract new investors to the system and training programmes will be offered with the purpose of structuring an investment network with interest in the knowledge created in Catalonia in the field of digital technologies as a whole, and particularly in artificial intelligence.

³² <http://catalonia.com>

4.2.2 Research and innovation

The competitiveness of Catalan companies largely depends on improving the productive model and increasing associated productivity. This change requires firmly supporting research and innovation, considering all the stakeholders in the Catalan system and, instead of seeking excellence, it needs to tackle real problems, especially in relation to knowledge transfer and the professional management of the associated activities.

In the present context, the key factors of Catalonia's international competitiveness are excellent basic knowledge and the capacity for technological development in artificial intelligence. In this regard, the different agents of research and innovation that work with artificial intelligence need to be promoted and coordinated, so Catalonia may become a pole of attraction in the creation and transfer of knowledge towards the different productive sectors.

4.2.2.1 Connection and strengthening of AI research and innovation entities

The Catalan research and innovation system has a high number of public and private research and innovation groups, institutes and centres that specialise in artificial intelligence; however, greater coordination and joint work is required to create sufficient critical mass to respond to the social needs and business challenges of the different areas of action.

In this regard, a centralised or network-based **operational structure** will be created or adapted with the purpose of promoting synergies between groups, institutes, universities, companies, research and innovation centres specialised in artificial intelligence, thus creating synergies and collaborations to boost joint activity at home and abroad. The members of the structure will work together to define the priority objectives in this field, in line with social and industrial requirements and encouraged by the new European research and innovation programmes for oncoming years.

An **Advanced Research and Innovation Programme** in the field of artificial intelligence will also be promoted in order to give additional support to research groups, institutes and public centres that carry out AI projects in Catalonia. Challenges will be established aimed towards resolving social or business issues related to artificial intelligence with adequate monitoring of the developed activities. This programme may be linked to the advanced digital technologies programme and will have the clear purpose of developing innovative solutions for industry that respond to real needs previously identified by associations and business entities, thus complementing the challenges provided by the governmental bodies associated to the previously mentioned programme. Like previous projects, they will be of a collaborative nature and will be exclusively addressed to public research and innovation centres, as well as technology-based companies that are in the process of technological development. One of the programme's priorities will be to combine different digital technologies, for example, artificial intelligence with the internet of things (IoT) and blockchain technologies, exploring the distributed intelligence models also related to future 5G networks.

Finally, great importance will be placed on supporting business **R&D+i** in AI, especially when it is carried out by companies with their own innovation centres or that plan to implement them in Catalonia in the near future. Support will be given to actions aimed towards setting up industrial pilot projects, prototypes or proof of concepts in real environments of advanced technology, seeking funding for innovations associated to business growth, fostering participation in international projects and making use of tax incentives. In conclusion, a double task aimed towards promoting and funding business initiatives that have taken the firm decision to create wealth and create employment in Catalonia.

4.2.2.2 Opening of the Centre of Excellence in Artificial Intelligence

Catalan companies and institutions need an immediate reference to be able to see for themselves how artificial intelligence will impact the different sectors of action and to receive the necessary guidance when they first adopt artificial intelligence, especially in the case of SMEs.

Within this context, the **Centre of Excellence in Artificial Intelligence (CoE AI)** will enter into operation, following the model of the Digital Innovation Hubs³³ set up by the European Commission. Said centre will provide companies and institutions with a reference and will work at their service to demonstrate the benefits of AI and accelerate the adoption of innovative technologies when applying artificial intelligence and using data created by the system as a whole.

The CoE AI, created as a network-based service centre, will become a key element of CATALONIA.AI in relation to promoting knowledge transfer and executing joint projects between knowledge-creating entities and companies and user institutions, which demand innovative AI solutions.

As regards SMEs, the centre will promote an AI application programme that will include activities focused on dissemination and awareness-raising, providing consulting services and guidance for digitisation, as well as offering support in the implementation of projects by way of digitisation vouchers used to implement ICT solutions, especially in the field of artificial intelligence.

4.2.2.3 AI knowledge transfer to boost business innovation

More and more companies are choosing open innovation as part of their business strategies, whether it is due to long development times, in the case of the pharmaceutical industry, or because staying at the forefront requires continuous technological updates, as in the case of the ICT industry. In respect to advanced technologies, like artificial intelligence, the specific circumstances are related to the latter, and therefore require a continuous development effort, particularly in the search for new applications for specialised sectors.

Within this context, it is essential to boost the mutual commitment of companies and public AI research and innovation entities by creating **mixed public-private networks, institutes and units** so as

³³ <http://s3platform.jrc.ec.europa.eu/digital-innovation-hubs>

to create strategic alliances, set up innovative joint projects, not just services, take advantage of the pulling effect of large companies and encourage a rational use of existing resources, infrastructure and technology platforms. Likewise, boosting clusters or the participation of sectoral business associations in the application of digital technologies will spread their use as a basis of industrial competitiveness, while developing new business models with an international outlook. In this regard, beyond the creation of possible programmes or collaboration projects, it is also important to make use of previously existing programmes, such as the Industrial Doctorates Plan,³⁴ CERCA Gínjol³⁵ or the Knowledge Industry,³⁶ with a special view that emphasises advanced digital technologies, particularly artificial intelligence.

A pending challenge related to the system as a whole, a key factor for knowledge transfer, also in artificial intelligence, is to drive a **specialised map of capabilities** to be able to connect technologies, services and local companies with international environments, as well as detect existing weaknesses in the business network and strengthen the identified fields of action, either as creators or users. This map applied to artificial intelligence will help make better use of the current capabilities of the Catalan research and innovation system, will foster collaboration between companies and private and public institutions and facilitate talent attraction and retention, domestic and international investment and technology, thus creating economic and social value.

Another key element in the relationships between knowledge-creating companies and public entities is trust, in the real technological capability and in terms of development. It is therefore necessary to position Catalan universities and research and innovation centres as **outstanding and trustworthy suppliers for companies**, based on the development of own technology, establishment of public and private collaborations and service provision. This positioning in the AI field will be accompanied by a definition of objectives and the establishment of innovation-based indicators that could have effects on the implementation of specific mechanisms that boost these activities, such as the creation of centres of excellence similar to those mentioned above.

It is worth noting the necessary effort for promoting the **incubation, acceleration and internationalisation of technology-based companies**, especially those arising from the research and innovation centres of the public system with AI-based technologies or which are directly applied to the productive sectors where there is an availability of existing technologies. In this regard, together with ACCIÓ, assessment programmes will be implemented to validate the business model, validate and attract the first customers and seek funding to obtain the necessary boost and be recognised as stakeholders of interest by medium and large-sized companies. Another outstanding feature is the collaboration that could arise with the previously existing acceleration and incubation programmes in the country, such as those linked to *Programa Catalunya Emprèn* (Embark Catalonia Programme)³⁷ driven by the ministry of Business and Knowledge or The Collider programme³⁸ of Mobile World Capital

³⁴ <http://doctoratsindustrials.gencat.cat>

³⁵ <http://ginjol.cerca.cat>

³⁶ http://universitatsirecerca.gencat.cat/ca/03_ambits_dactuacio/Transferencia-de-coneixement/programa-industria-del-coneixement/

³⁷ <http://catempren.gencat.cat>

³⁸ <https://thecollider.tech>

Barcelona, as well as others of the private sector, such as Seedrocket, Conector, Ship2B, Wayra and BStartup, which include own public and private initiatives that could be highly relevant for the Strategy.

4.2.2.4 Innovative public procurement as an AI development path

Through the Horizon 2020 research and innovation programme and the initiatives related to the European Institute of Innovation and Technology (EIT),³⁹ especially the EIT Digital Community,⁴⁰ in recent years the European Commission has developed different **innovative public procurement** projects, particularly in the healthcare sector, which are added to public initiatives habitually carried out in our system through the Public Procurement Platform. Together with pre-commercial public procurement, still under development, this action constitutes a fundamental element for the future of artificial intelligence in Catalonia, not only because of the public funds it involves but also due to the mobilisation of the existing technologies in the productive network, the boost of proofs of concept in different fields and the participation of the set of stakeholders of the research and innovation system.

With the wish to convert Catalonia into a leading pole of attraction in artificial intelligence in oncoming years, the CATALONIA.AI Strategy and the Advanced Digital Technologies Programme have established as priority that the services of the government of Catalonia put out to tender by the different ministries must respond to challenges of Public Administration as a mechanism to attract collaborative projects and proposals from public and private research and innovation agents as a whole. In this regard, priority will be given to entities responsible for the project with equipment, prototypes and/or AI innovation projects when the request for proposal is issued and, especially if these projects have been developed within the framework of European initiatives or have been funded by programmes associated to RIS3CAT or similar.

The ultimate goal is to ensure that AI technologies impact the government's different departments and respond to both current needs and new services and projects of the different ministries. Preference will be given to tenderers with their own equipment that can be used in related projects in different testing environments, such as health, agriculture, mobility, industry, culture and education, among others.

4.2.3 Talent

The existing talent in Catalonia is a necessary and indispensable resource for promoting the development of the AI ecosystem; it is therefore strategic for the region to provide citizens and professionals with the required competencies and capabilities to effectively apply artificial intelligence in Catalonia. Within this context, it is essential to have adequate training that guarantees the deployment and uptake of the technologies associated to artificial intelligence in order to continuously produce new professionals that fulfil social and business requirements.

³⁹ <https://eit.europa.eu/>

⁴⁰ <https://www.eitdigital.eu/>

4.2.3.1 Talent management in AI: creation, attraction and retention

Programmes for research talent in AI

Initiatives for improving the offer of universities will be promoted and supported with courses, seminars, master's degree and postgraduate degrees in the technology and non-technology fields related to artificial intelligence with the purpose of satisfying the needs of current and future professionals. Within this context, university-business collaboration mechanisms will be implemented with the purpose of better-adjusting the curriculum to social and business requirements that boost innovation and research centred on providing technological solutions.

As regards official postgraduate courses, master's and doctoral degrees in artificial intelligence, specific action will be taken to know the situation in the different universities and promote top-quality, professionalising and participative programmes partly funded by institutions and companies that use the technologies in different fields of activity, while considering the possibility of establishing one or more inter-university courses. The action will be carried out by a working group consisting of representatives of universities, knowledge-creating entities and entities that use AI technologies, so as to exchange knowledge, experiences and establish appropriate content and the most effective collaboration mechanisms. At the same time, work will be carried out to internationalise the courses, with the purpose of attracting international students and fostering relationships with top-level entities and specific content. This will be achieved by way of the Erasmus+ programmes through the KA2⁴¹ collaborative actions and Initial Training Network (ITN-Marie Curie⁴²), respectively, as well as others that could be implemented in our system in the future, with a view to predoctoral researchers (R1).

In relation to teaching and research staff involved in advanced digital technologies, especially artificial intelligence, who have reached junior postdoctoral (R2) and senior postdoctoral (R3) stages, with the inclusion of Catalan and international talent that is currently distributed all over the world in foreign research centres, specific actions will be carried out with the purpose of creating a proprietary programme, CATALONIA.AI TALENT, based on some of our successful models, like the current ICREA SÈNIOR⁴³ or previous ICREA JÚNIOR, which may benefit from co-funding opportunities offered by smart specialisation programmes and the European Social Fund, the real co-funding options of research and innovation centres and the activities associated to the Marie Curie programme within the Horizon programme, especially the Cofund scheme.⁴⁴ This will guarantee more resources and increased presence of advanced digital technologies in general, and artificial intelligence in particular, throughout our research and innovation system.

Programmes for innovative talent in AI

In recent years, the Catalan university and research system has reached renowned levels of excellence. Now is the time to deploy suitable actions to transfer the accomplished level to society, especially to the productive and business network, mostly consisting of SMEs, in such a way the knowledge may

⁴¹ https://eacea.ec.europa.eu/erasmus-plus/actions/key-action-2-cooperation-for-innovation-and-exchange-good-practices_en

⁴² <https://ec.europa.eu/research/mariecurieactions/>

⁴³ <https://www.icrea.cat/es/la-seleccion-de-icrea>

⁴⁴ https://ec.europa.eu/research/mariecurieactions/actions/co-funding-programmes_en

also create wealth, employment and social improvement. Within this context, it is essential to encourage professionals in universities and research and innovation centres to work together with experts from companies, foster permanent contact by forming joint teams and favour knowledge transfer.

The development of research and innovation in Catalonia is structured into different levels, universities, centres, networks, departments, consolidated groups and, lastly, individual researchers, which form a complex ecosystem that is not always well coordinated. As regards this point, the announcement of grants to support the activities of research groups⁴⁵ (SGR) provides the opportunity to have an advanced map of the existing groups and, in the case of artificial intelligence, those that work in any area of knowledge. To this end, actions will be performed focused on boosting training and attracting projects related to these groups, while working on a similar map for private knowledge-creating entities, companies and user institutions. Subsequently, work will be carried out to take maximum advantage of the opportunities offered by the Industrial Doctoral programme implemented a few years ago in Catalonia, which has leading names from Spain and Europe. The programme will act as a preferential path to connect public centres, institutions and companies interested in digital transformation and the application of AI technologies. The results obtained and eventual synergies could be the embryo of new approaches to attract talent, for example, by establishing mixed public-private AI units or specific consortiums.

In parallel, thanks to European funds associated to initiatives such as RIS3CAT, Cofund and own resources of the private sector, and as part of the CATALONIA.AI TALENT programme, work will be carried out on an initiative for **attracting digital talent** to enable permanent contact between research and innovation centres and companies, possibly within the framework of CATALONIA.AI COMMUNITY or associated sectoral networks, thus providing investigational and innovation mobility, following models such as Tecniospring, Beatriu de Pinós Empresa, Connect-EU, Marie Curie Incoming and Outcoming Grants, and Torres Quevedo, in connection with incubators, innovative companies and national and international research and innovation centres.

A final very significant fact, albeit rather under-developed, is the lack of professionals dedicated to connection within the research and innovation system, other than the people working in offices where research results are transferred. The majority of these people have hardly any experience in the digital field and even less in AI technologies. In this regard, the support obtained from universities as a result of the announcement of grants to carry out knowledge-transfer and assessment unit projects is the first step for strengthening activities centred on connecting the system as a whole, although it is insufficient if we limit ourselves to the general field of digital actions, and artificial intelligence in particular, while excluding the rest of research and innovation centres. For this reason, there are plans to promote an activity as part of the CATALONIA.AI TALENT programme and co-funded by other receiving centres, with the purpose of incorporating **digital innovators**, who will work in a network and manage innovation and digital knowledge-transfer in a specific area of action, such as innovators or

⁴⁵ <http://agaur.gencat.cat/ca/beques-i-ajuts/convocatories-per-temes/Ajuts-per-donar-suport-a-les-activitats-dels-grups-de-recerca-SGR>

entrepreneurs in residence to attract ideas and new projects to be developed, as a reference for companies and institutions interested in digital technologies and linked to artificial intelligence.

Collaboration with the Barcelona digital talent alliance

To ensure Barcelona and Catalonia's competitiveness as a technological pole in advanced digital technologies as a whole and, specifically, artificial intelligence, the government of Catalonia in collaboration with other public and private institutions has set into motion the BARCELONA DIGITAL TALENT⁴⁶ alliance, with the idea of positioning Barcelona as a place with the capacity to create, retain and attract talent with the necessary knowledge and capabilities to develop this new industry.

Barcelona Digital Talent is an alliance created with the purpose of positioning the city of Barcelona as a pole of digital talent, thus responding to the lack of specific talent in the city and the increase of technology-based businesses that need profiles with digital competencies. Barcelona's experience is highly relevant for the entire region; consequently, work will be carried out with other members of the alliance to create other poles within Catalonia that can replicate the experience and form other alliances between companies, public bodies and training centres, similar to the one described for Barcelona. This territorial digital component, which will be included in the CATALONIA.AI TALENT programme, will give preference to talent associated to AI development and will spread this ability to create, retain and attract talent to the rest of Catalonia.

The work established in the programme will have three facets: promote digital technologies throughout the region, know the existing professional profiles and identify business requirements. Likewise, training programmes will be drawn up to satisfy existing needs and will focus on training well-qualified professionals, ranging from university courses to vocational training programmes and the development of vocational training in these fields of knowledge. Finally, working in direct contact with companies and user institutions, priority will be placed on developing a professional career in artificial intelligence and in identifying Barcelona and Catalonia as an international place of reference. All these activities may be co-funded in collaboration with the Servei d'Ocupació de Catalunya (Catalan Employment Service), by way of the innovative and experimental project programme, use of funds from the European Social Fund, initiatives associated to the Erasmus+ programme and own resources from the interested private sector.

Programmes for entrepreneurial talent in artificial intelligence

Artificial intelligence will make it easier to create new applications that may be offered in different fields of the productive and social network. This will entail the appearance of new companies and entrepreneurial programmes, whose objective is to implement and market these technologies in different sectors, as a renewal point of the Catalan productive network, particularly as regards knowledge-creators and making professional development really possible for scientists and innovators in Catalonia.

⁴⁶ <https://barcelonadigitaltalent.com>

In this regard, as part of the Embark Catalonia Programme of the government of Catalonia and the associated Xarxa Emprèn network, projects will be promoted to foster entrepreneurial talent in the AI environment, while putting priority on this technology in existing programmes in Catalonia that are directed towards fostering technological development; for example, the INNOVAR Programme through start-ups,⁴⁷ driven by ACCIÓ or the Knowledge Industry Programme developed by AGAUR.

An example of this kind of initiative is the programme called AI4ALL, Artificial Intelligence Applied to Industry,⁴⁸ promoted by the UAB Research Park, the Computer Vision Center and the Autonomous University of Barcelona with the purpose of bringing AI technologies closer, create new market ideas and help boost Catalonia's competitiveness in this field. This initiative forms part of the programme to promote specialised entrepreneurship in the territory (a pre-accelerator programme) and constitutes an embryo of great value as regards developing a programme with a general scope. The work will be carried out in collaboration with the territory, the Catalan Employment Service and the institutions that use AI technologies, rather than coordinating with other existing public or private initiatives. In this regard, a programme of reference will be promoted based on existing good practices, in collaboration with public and private stakeholders, especially training centres, research and innovation centres, business associations and entities that use AI technologies.

In the same way, taking advantage of the opportunities linked to European programmes, efforts will be made to create an entrepreneurial community in the field of AI technologies, based on the possibilities offered by the Erasmus+ programmes. This will be achieved by strategic alliances, programmes developed by consortiums and the Competitiveness of Enterprises and Small and Medium-sized Enterprises programme (COSME⁴⁹), through the Erasmus programme for young entrepreneurs, which will enable exchanges between new entrepreneurs and experienced European entrepreneurs through the creation of consortiums. In this regard, an initiative associated to Advanced digital technologies will be developed, especially artificial intelligence, which includes the European countries that have made the most progress in the subject.

Training in artificial intelligence for everyone

Artificial intelligence forms part of our daily lives and in the future, it will have an even greater impact on all industries and individuals. Everyone will have the chance to understand what artificial intelligence really is and the way it could impact our lives; for this reason, it is a priority to democratise the knowledge of these technologies and empower citizens so they may play a more active role in its deployment.

In this regard, CATALONIA.AI includes the implementation of a training programme for citizens, to teach the basics of artificial intelligence to anyone interested in this technology. The programme will consist in offering free courses that will adjust to each student's needs and capabilities, taking advantage of existing educational technologies, such as massive open online courses, classroom-based and online employment and ongoing training programmes, as well as other activities that may be

⁴⁷ <https://barcelonadigitaltalent.com>

⁴⁸ <http://www.accio.gencat.cat/ca/serveis/innovacio/startups-i-innovacio-disruptiva/innovar-a-traves-de-startups/>

⁴⁹ https://ec.europa.eu/growth/smes/cosme_en

carried out throughout Catalonia, drawing on collaboration with the corresponding public bodies of the ICT network⁵⁰ and CatLABS network,⁵¹ which already exist, or working in cooperation with technological parks and training entities.

To develop this initiative, an agreement will be established with similar international initiatives that have a successful track record, like the course created by the company Reaktor and the University of Helsinki, **Elements of AI**,⁵² which already has 170,00 students from 110 different countries.

Besides the programme's dissemination campaign, agreements will be made with companies and Catalan institutions so they may promote training among their collaborators, therefore reaching the maximum number of entities and citizens in the country.

Foster vocations in artificial intelligence

In a digital society it is absolutely necessary to train both present and future users. In this regard, schools and the younger students need to know, have contact and be familiar with cutting-edge technological tools, such as artificial intelligence.

Children feel drawn towards a vocation during their first years at school. This means having to design an effective vocational plan in artificial intelligence within the framework of the STEMcat Plan, implemented by the government of Catalonia. The Plan should not only include activities in primary and secondary schools: working with families, giving talks, organising workshops, providing support networks, carrying out specific activities in schools and preparing the corresponding teaching and audio-visual material, but it should consider redesigning primary and secondary curriculum plans to include content that stimulates computational thinking and prepares students for artificial intelligence, incorporating gender perspective and training teaching staff to introduce this content.

Likewise, within the field of vocational training, it is necessary to guarantee training pathways that are directly linked to Catalonia's social and economic requirements, placing special emphasis on advanced digital technologies, not included at present as a training speciality in intermediate and higher level training programmes of the Information and Communications family, apart from specific profiles like cybersecurity and bioinformatics. Given the lack of digital talent detected, it is indispensable to establish a specific programme in advanced digital technologies, at intermediate and higher level vocational training, which ensures a better and fuller inclusion in the employment market and takes advantage of the potentialities currently offered by the dual vocational training, among other aspects to consider.

4.2.3.2 Boost the role of women in artificial intelligence

The extremely low presence of women in the technology industry is a well known fact. According to a study drawn up by the Catalan Women's Institute,⁵³ only 30% of the jobs in the Catalan ICT industry

⁵⁰<http://www.punttic.gencat.cat/>

⁵¹<http://catlabs.cat/>

⁵²<https://www.elementsofai.com/>

⁵³<http://dones.gencat.cat/ca/detalls/Noticia/Dossier-TIC-2019>

are held by women. Bearing in mind that the report published in November 2018 by the European Center for the Development of Vocational Training⁵⁴ forecasts that by 2025, 84.5% of jobs will be in the technological field, the low presence of women in the industry means that in the near future, they will run the huge risk of being excluded from employment for gender reasons.

In the field of universities, the number of men studying information and communications technologies is four times higher than the number of women; in the case of computer engineering, one of the core degrees in the field of artificial intelligence, the situation is worse, as there is only one woman for every 10 men studying this degree in Catalonia.

The last factor of the equation is that artificial intelligence is an emerging sector in full growth. In fact, according to a report published by Randstad, the demand of technological professions in Europe will increase every year by 14% until 2025, and artificial intelligence is at the head of this movement. Thus, the number of professionals required by AI is much higher than the number created by universities. At the moment, there is a significant lack of professionals, which practically determines full employment in the sector.

Consequently, we are faced by a picture where there are not enough women at all levels of the ICT industry, especially in decision-making positions, and their presence in university degrees that qualify them for this sector is extremely low. However, there is room to reverse this trend as the offer is sufficiently large for everyone.

It is important to work towards rebalancing the presence of women in the sector for a number of reasons:

1. The intention is to comply with article 32 of Act 17/2015, of 21 July, on effective equality between women and men and establishes measures to ensure equality between men and women in access to work, vocational training, professional promotion and working conditions.
2. Given the lack of professionals qualified to work in the general ICT industry, there are huge opportunities to access the employment market of this sector, particularly for women. Consequently, in view of the trend of the employment sector, access to the employment market is guaranteed for women with technical qualifications.
3. A plural view always enriches the exercise of professions and ICT is not an exception. A feminine view is necessary to build a comprehensive and equalitarian future. Women's perspectives create quite a conclusive differentiating factor: according to Forbes, whenever women have led projects and/or companies, they have overcome situations of crisis with greater success.

There are basically two critical points in this aspect: very few girls have a technological vocation, so their interest in technology-based professions needs to be awakened and they must be encouraged to study scientific and technical degrees, and women encounter difficulties when it comes to exercising leadership in the sector, which implies promoting the participation of women in the management of organisations in technological fields.

⁵⁴ <http://www.cedefop.europa.eu/>

Catalonia is aware of the situation and a first network of agents is currently tackling the problem. The government is deploying the Pla Dona TIC (Women's ICT Plan), promoted by the Catalan ministry for Digital Policy and Public Administration, thus providing an institutional protective framework for boosting female presence in the ICT industry. In recent years, emblematic entities of the AI sector have set a benchmark with their gender structures in these matters, for example, the Col·legi Oficial d'Enginyeria Informàtica de Catalunya (Catalan Association of Computer Engineering) and the gender-gap commission, Dones COEINF, the Catalan Association for Artificial Intelligence and the donesIAcat working group and the UPC with its Aquí STEAM programme, which, in turn, collaborate with other entities to study the gender gap in artificial intelligence and computer engineering and help reduce it.

In this regard, the CATALONIA.AI Strategy will focus on drawing up an action plan that will be developed within the framework of the Pla Dona TIC, implemented by the government of Catalonia, with the collaboration of different existing initiatives. The plan will have the following objectives:

- Encourage early vocations in technology;
- Balance the presence of women in ICT training and skills within the field of vocational training, university studies and postgraduate courses;
- Foster ongoing training that requalifies women so they may enter the AI sector;
- Ensure women have equal rights to access employment in the sector;
- Enable mechanisms to encourage women to continue exercising the profession within the field of artificial intelligence throughout their entire working lives;
- Encourage companies, entities, and public and private bodies to establish professional careers that enable women to reach leadership positions with equal opportunities;
- Especially prevent the flight of female talent and encourage migrated human capital to return.
- Establish a legal order for gender-related actions in the field of artificial intelligence and technologies in general to increase the effectiveness of actions aimed towards achieving the objectives described above in which women and men collaborate together under these guidelines.

It is important at all levels to make known and give visibility to successful women, both in schools and the Catalan society in general. This may be carried out on a small scale by giving talks in the different forums mentioned above, awarding prizes to recognise the achievements of women in technology (there are already a few in Catalonia), or at a larger scale, by means of actions on social media, coordinated with well-known influencers or influencers like YouTubers or YouTube personalities with the highest number of followers, writing stories or comics where women appear with technological roles and their presence in the media, news programmes or series where visibility is given to these leading names or which show what it means to develop a profession in the field of artificial intelligence.

As regards leadership, the development of a plan to support women's working lives in the AI field that combines services related to professional guidance, requalification, ongoing training, work-life balance and professional promotion that respects the specific conditions of females in professional development and the system of valid accreditations. Incentives for companies with female managers,

subsidy programmes in the field of artificial intelligence led by women (at either a professional or research level) could effectively help reverse the current trend in the sector.

A fourth pivotal element will be the establishment of mechanisms to identify and quantify the flight of female talent in the past and institutional actions will be designed to facilitate the return of this talent.

Several small actions are currently underway in many fields: schools, companies, entities and institutions that work in this direction, donesCOEINF, donesIAcat, the fent.talent platform and the Aquí STEAM programme are just a few examples, though there are many more. It is essential to identify, arrange and coordinate these actions, strategically integrating them into more effective instruments in the Catalan society, so they may work as a whole with greater strength, thus increasing their impact, which will be appropriately monitored and measured. As mentioned above, the establishment of a general regulation would help multiply the effect of this network, which is already in operation.

It is worth pointing out that all these actions will only be possible if they are performed by women and men working together. Furthermore, even if the necessary resources are provided, the actions would not be possible without the tireless work carried out by volunteers, who are currently moving them forwards. Consequently, both women and men, as well as institutions need to be made aware of the matter.

4.2.4 Infrastructures and data

One of the European Commission's priorities in its strategic proposal for the development of artificial intelligence in Europe is precisely making the access to data easier and more secure to be able to explore and deploy all the potentialities of artificial intelligence. In fact, without quality data it would not be possible to properly develop artificial intelligence; therefore, the Catalan strategy also considers that accessing and sharing data with the aim of developing products and services with artificial intelligence is one of the first priorities.

4.2.4.1 Promotion of laboratories and infrastructures

The rapid evolution of the market, not only in the field of artificial intelligence, but also in the general technology field, and a need to search for good solutions to problems that must be fast and smooth when accessing the market, as well as capable of adapting to the market's reality translates into the need to create a prototyping environment that allows to share experiences, data, algorithms, modules, computer capacity, etc. in order to test and adapt solutions to the market.

CATALONIA.AI LAB will be implemented as a sharing and testing environment that acts as a window open to ideas and surrounding initiatives, which can then be gathered and classified: social innovation by people for people. It has a dual purpose, to promote the technology sector offering access to infrastructure and boost open innovation with companies and public bodies through their participation in pilot tests.

The work in this field will also count on the collaboration of specialised research and innovation agents to provide the projects with existing computer and data-analysis infrastructure; for example, the

Barcelona Supercomputing Center, Institut de Robòtica i Informàtica Industrial, the Industrial Platform 4.0 or the labs and demonstration area of the Centre of Excellence in Artificial Intelligence, among others.

4.2.4.2 Access and sharing of data

One of the essential and differentiating components of an artificial intelligence system are the necessary data to feed any AI system and its appropriate training process. The quality of the dataset, the iterations and the suitability of the algorithm training are very important in any AI project.

As regards this point, the following actions will be promoted:

- Publish and make available quality open data and improve local research groups' access to the information and enable the use of verified information that helps develop the best solutions possible.
- Promote and participate in markets of correct and secure data with other AI communities and ecosystems. The volume and diversity of the data largely contribute to the quality and excellence of the results obtained.
- Promote the production and donation of open and private data as a fundamental right of the person and as a legacy of quality and social benefit.

4.2.5 Adoption of artificial intelligence

Although at first AI techniques were created with large technology-related companies in mind, more and more companies and public bodies are starting to adopt AI-based solutions. This is due to different factors: better and cheaper computer capacities, increased and better features in mechanical and repetitive processes, increased availability of corporate and external data, development of prediction capacities and an increasingly more positive correlation between applicability and benefits.

In this regard, one of the most important pivotal elements of CATALONIA.AI will be to foster and accelerate AI adoption processes in Catalonia's different industrial sectors, as well as in Public Administration itself.

4.2.5.1 Public Administration as a pioneer in the application of artificial intelligence

Public Administration is a major data creator, manager and container; therefore, it has to lead and set an example as a user of artificial intelligence. The objective is to become an **intelligent, efficient and transparent administrator with digital, proactive and personalised public services** that simplifies the relationship between citizens and optimises their management through process automation.

The application of artificial intelligence at the service of the public offers citizens direct and indirect benefits. The direct benefits include those resulting from the application of artificial intelligence to respond to citizens' specific needs. Artificial intelligence facilitates and speeds up customer services, it

makes it easier to fill in forms, pay taxes, diagnose illnesses, take decisions and protect personal data, etc. This new typology of solutions redounds in indirect benefits, improving the quality of public services, whether it simplifies processes, increases efficiency, controls fraud, optimises resources or enables smart management.

The Catalan Public Administration has to be the driving force behind AI solutions. Guided by the different government ministries, together with the pertinent bodies it has to gradually adopt AI solutions. However, the goal will only be achievable if it has reliable data and a suitable testing environment for improving public services; it will also be necessary to promote a set of initiatives aimed towards accelerating the uptake of innovative technologies when using the data and artificial intelligence, which include the following:

Opportunity detection programme

To enable Public Administration to boost the use of AI technology, a first line of action will be to set up a programme to detect and analyse use cases and improvement opportunities for the different departments and bodies of the government of Catalonia.

The goal is to determine how the government of Catalonia and citizens will benefit from technologies of this kind, in regard to specific applications.

AI observatory for Public Administration

Given the speed at which these kind of technologies are developed and implemented around the world, an AI observatory will be set up, which will take charge of identifying, classifying and analysing the trends, evolution, technological development and deployment of artificial intelligence, both in Catalonia and abroad, as well as assess the different initiatives underway in Catalonia and share the conclusions and created knowledge.

Development of use cases

In view of the different points mentioned in this section, the government of Catalonia will promote the development of proofs of concept and projects that use AI technologies in the different governmental areas, with the purpose of improving public digital services.

In this regard, an interministerial working group will be created that will be in charge of identifying, prioritising and boosting the deployment of this technology in the different departments and bodies of the government of Catalonia.

CATALONIA.AI CHALLENGE

In order to involve developers, entrepreneurs, start-ups, and small and medium enterprises of Catalonia's AI ecosystem so they may create new technological solutions, there are plans to launch CATALONIA.AI CHALLENGE, a competition that connects the problems and challenges raised by Public Administration with the proposals offered by the Catalan AI ecosystem, in order to develop proofs of concept and innovative solutions that respond to the outlined challenges.

4.2.5.2 The development of artificial intelligence in strategic sectors

The characteristics of AI technologies will lead to the appearance of new products and services specifically aimed towards key economic sectors, including transport, health, the manufacturing industry, logistics and the media, thus enabling them to make use of the benefits of disruptive innovations and improve their competitiveness in comparison to other international environments. Likewise, AI technologies are frequently in the pipeline, although there are already effective products in the market; consequently, different technological waves are expected, meaning that continuous cooperation between the different stakeholders of the ecosystem is even more important.

In this regard, a **sectoral revitalisation programme** will be set in motion to attract business and social challenges, with the aim of developing specific services and solutions adapted to existing needs. Co-creation activities will be carried out to generate proposals that join the supply and demand in different sectors into a single space, so as to analyse potential use cases, view success stories and identify required proofs of concept, taking advantage of existing programmes or new options that could appear. Within this context, the connection activities may be developed as scientific-business forums or gatherings, or through connections with clusters and associations that guarantee maximum effectiveness and sectoral representation, together with the support of the different government departments and local public bodies that promote technological initiatives of a sectoral nature.

It is therefore a matter of identifying the main use cases applicable to artificial intelligence in each sector, disseminate them among businesses and accompany them in their implementation process. Whenever necessary, companies will be encouraged to carry out research and innovation in artificial intelligence, whether it is internal or external (in this case especially fostering technology transfer with the TECNIO Centres). The centre of excellence in artificial intelligence referred to above will be the most suitable environment for starting many of these initiatives.

The development of this sectoral revitalisation programme will involve prioritising fields where artificial intelligence is used, according to the leading sectors of RIS3CAT, which does not rule out development in strategic projects in other fields. The priority sectors are initially the following:

Agri-food industry

The agri sector (agriculture, livestock, fishing and silviculture) and agri-food (manufacture of food and drink) represents 17% of the Catalonia's industrial gross domestic product (GDP). During the last 20 years, the sector's transformation capacity has converted the agri-food industry into a fundamental part of Catalan manufacturing and, at the same time, into one of the main driving forces behind the change and transformation of the region's economic model. With over 3,500 companies, the agri-food industry is the industrial branch in Catalonia with the highest turnover, it is the main export sector and is Europe's top agri-food cluster.

The application and use of artificial intelligence would focus on optimising natural resources and from the very beginning it is closely linked to the internet of things (IoT), which would increase the efficiency and traceability of agricultural operations.

The energy saving and optimisation of natural and own resources open up a wide range of possibilities to be explored. Considering the weight of the sector in Catalonia, this would be one of the priority sectors to develop.

Health and well-being

The health sector is one of the fields where the use of artificial intelligence has the longest history and a greater projection. This prioritisation is based on two main vectors: increased life expectancy and the projected savings from using artificial intelligence in health.

In the mental health field, artificial intelligence can contribute with innovative non-invasive diagnostic procedures to identify illnesses before symptoms appear and help with profitable triage techniques. Speech and writing analyses are already used among other techniques to detect changes in behaviour and even suicidal tendencies. AI-powered social robotics could provide alternative therapies that go beyond conventional treatment; for example, helping people who suffer autism spectrum disorder.

The wide variety of existing medical data (for example, the clinical records of people living in Catalonia), protocolisation of diagnoses and treatments, advances in computer vision and speed with which a large amount of information can be interpreted, used and accessed, in addition to current trends in preventive and personalised medicine, mean that there is a wide field of research for artificial intelligence and it can provide a high amount of value.

Furthermore, the pharmaceutical industry is one of the sectors that benefits from these techniques by using supercomputing and simulation to create and assess new medicinal products.

Experienced-based cultural industries

The sector known as experiences comprises tourism and culture. The technology applied to these two industries can improve and increase productivity and promote offers and services, while providing information about the offer of competitors and the behaviour of potential customers. In this regard, AI techniques have great potential in specific topics such as marketing, social media management, personalisation of experiences, customer loyalty, improvement of the existing offer, etc.

Another feature worth pointing out, of a cross-cutting nature, is that artificial intelligence can be used to analyse and interpret existing data gathered from all this activity, thus improving future plans and strategies.

Mobility

This sector encompasses all the agents that work to develop solutions to make mobility and transport more sustainable: the automotive industry (manufacturers and suppliers), railway industry, physical infrastructures, transport and infrastructure operators, fleet managers, the logistics industry and advanced mobility of people, ICT services (mobile technologies, V2X communications, self-driving cars, etc.), energy distributors, the energy supply industry (electric vehicle charging points, alternative fuels, etc.), public bodies and other institutions with authority in the management and safety of transport in

Catalonia, or promoters, legislators or users of corporate fleets, universities, research centres and technology centres, as well as individual or collective users, for private means or as a company/entity.

Self-driving vehicles, new means of transport, traffic planning and management, such as the adaptive traffic signal control system, are just a small example of the fields of application of data convergence, the internet of things and artificial intelligence. Reduce pollution, prevent accidents and provide everyone with transport and the possibility to move around are the priorities of this field.

Energy and sustainability

Technology can become a catalyst for social innovation, the internationally approved common framework to orchestrate the action of responsible technology in society, within the 2030 Agenda for Sustainable Development. These are the SDGs (Sustainable Development Goals for 2030) On 25 September 2015, the United Nations identified the 17 sustainable development goals that act as guidelines for social and business action. The fact that the United Nations recognises the use of data as a mechanism for revolutionising social systems has led to different international data-based initiatives (for example, data4sdg.org and undatarevolution.org) to approach this matter. For this reason, artificial intelligence plays a key role in the development of this new framework and the implementation of the SDGs, one of the government's priorities.

The contribution to circular economy, the fight against climate change and sustainable energy are fields where artificial intelligence can and must contribute more.

Industry 4.0

Industry 4.0 will transform design, production systems and the products themselves. It is estimated that connectivity between all the systems (known as cyber-physical systems) throughout the value chain and going beyond a single company, along with the interaction between the different parts, machines and humans, will make production systems 30% faster and 25% more efficient. Furthermore, it will take mass customisation of products to new levels. Manufacturing will go from automated individual parts to fully integrated automated facilities that communicate between each other. It will be possible to compile and analyse data between machines, which will lead to faster, more flexible and efficient processes to produce higher-quality goods at a lower cost. This will increase productivity, foster industrial growth, modify the workforce profile and redefine the dynamics of global competitiveness in companies and regions.

Artificial intelligence associated to industry 4.0 will play a fundamental role, as it facilitates the transformation of data into knowledge by creating expert systems based on algorithms, predictive models or machine learning solutions, so as to analyse data and facilitate decision-making, or also incorporate smart functions into their components or associated systems, to access their full traceability, their customisation according to customers' requirements or the generation of new disruptive business models based on the collection, analysis and use of the created data. In conclusion, to increase competitiveness within industry 4.0, artificial intelligence will have a decisive role.

Within this field, the government of Catalonia is promoting the Industry 4.0 programme to encourage technology transformation in companies established in Catalonia, including services and the

technological capabilities associated to the use and implementation of solutions for AI-based companies.

4.2.6 Ethics and society

It is necessary to guarantee that the uses of artificial intelligence are focused on humans' well-being: artificial intelligence must be developed, applied and used with an ethical purpose based on fundamental rights, our social and cultural values, and the ethical principles of beneficence, autonomy of human beings, justice and the necessary explainability of their results. Important grounds when working towards achieving a really secure artificial intelligence.

The design of new applications and tools based on artificial intelligence must pay special attention to situations that affect vulnerable groups, such as children, disabled people, elderly people or minorities, or asymmetric situations related to power or information, such as those between employers and employees or companies and consumers, and be aware that artificial intelligence, even if it offers considerable benefits for people and society, it could have a negative impact. Public Administration and society need to be aware of these matters of special concern.

Mechanisms and requirements need to be incorporated to ensure the security of artificial intelligence, and must include elements to be able to audit and evaluate algorithms, procedures and traceability of the use of these technologies. Artificial intelligence should be used in a responsible, sensible and secure way and must include ethical reasoning, in terms of following and maintaining tradition and the European differentiating fact for everything that affects people and their development, as well as guaranteeing justice, transparency and lawfulness.

4.2.6.1 Creation of the AI Ethics Observatory

Among other fields, CATALONIA.AI has to stand at the helm of ethics and good practices in the use and design of artificial intelligence. It must not only adhere to the ethics guidelines for secure artificial intelligence presented by the European Commission, the Barcelona Declaration of March 2017 and Montréal Declaration of December 2018, but also propose actions, ideas and principles to safeguard ethical and legal principles centred on people's well-being, the ultimate goal of artificial intelligence.

The Observatory will create a working group that will investigate ethical impact, establish guidelines to publish the best practices in this field and share this knowledge and work with other international bodies, especially The Partnership on AI⁵⁵ and The AI4EU Platform.

4.2.6.2 Promotion of spaces to debate and reflect upon the impact of AI on society

There is absolutely no doubt that artificial intelligence will impact our society, although people are beginning to ask if the impact will be positive or negative. In this regard, society is starting to demand

⁵⁵ <https://www.partnershiponai.org>

a certain ethical framework that defines the basic principles for a sustainable and responsible development of artificial intelligence; as a result, competent institutions and leading groups in the subject have begun to respond to this social demand.

It is important to open this debate to society as a whole, not just leave it in the hands of experts; spaces should be provided where people can reflect upon the purpose of artificial intelligence and how it benefits citizens. These spaces for reflection must include dissemination activities and, at the same time, be in contact with other international communities so they can join in the debate. These actions need to result in a true story that puts an end to the false ideas surrounding artificial intelligence and clarifies the benefits and risks we will face if we do not ensure the technology is developed in an ethical and responsible manner.

In this regard, CATALONIA.AI will collaborate with the Digital Future Society programme,⁵⁶ implemented by the Mobile World Capital Barcelona, which includes a global think tank focused on analysing the impact of technology on society. One of the main topics under study is the impact of artificial intelligence. The goal is to connect the local ecosystem and the conclusions obtained in Catalonia with international agents and experts participating in the programme.

In addition, citizen science activities will be launched with collaboration of the CatLABS network, driven by the government of Catalonia with groups to stimulate the activities, where citizens may experiment with artificial intelligence for themselves and provide us with their own conclusions. An example of an activity in this field is ExperimentAI,⁵⁷ promoted by the Computer Vision Center and the Autonomous University of Barcelona in the Library Living Lab of Sant Cugat. The project's main purpose is to help democratise universal access to knowledge and innovation for everyone, by starting up a co-creation space to enable citizens, different social stakeholders and professional groups to respond to the challenges society face as the result of computer vision technology and artificial intelligence.

⁵⁶ <https://digitalfuturesociety.com/>

⁵⁷ <http://librarylivinglab.cvc.uab.cat/calendar/experimentai-the-impact-of-artificial-intelligence-in-society/?lang=es>

5. Conclusions

It is evident that artificial intelligence plays a leading role in a technological revolution that will considerably transform society and economy. Catalonia has to develop and execute a strategy in this regard that is capable of turning this transformation into an important contribution that will benefit society and the business and economic network of the entire territory.

Catalonia has excellent capabilities that make it an ideal country to stand at the forefront of artificial intelligence. These capabilities include research and innovation capacity, the available supercomputing, robotics and telecommunications infrastructures that already exist, research centres with a consolidated reputation, capacity and experience, a notable position as a country for attracting investment and talent, start-ups and previously established companies, a first-rate digital ecosystem and the fact that Barcelona is the World Mobile Capital and venue of the world's most important technology fairs.

The government has put priority on promoting artificial intelligence and aims to support the deployment of AI technology, thus making Catalonia a renowned pole of attraction for research, innovation and talent, companies and investors in the field of artificial intelligence.

With this objective, the government is promoting Catalonia's Artificial Intelligence Strategy. Under the name of CATALONIA.AI, it will deploy a programme of specific actions to strengthen the AI ecosystem existing in Catalonia and lead knowledge generation, social and business application and create solutions based on artificial intelligence aimed towards fostering economic growth and improving people's lives.

Catalonia's Artificial Intelligence Strategy is coordinated by the Secretariat for Digital Policy of the Catalan Ministry for Digital Policy and Public Administration of the government of Catalonia, with the direct collaboration of the Secretariat of Business and Competitiveness and Secretariat of Universities and Research of the Ministry of Business and Knowledge, and the participation of the remaining ministries.

CATALONIA.AI will deploy a multi-sectoral, cross-cutting strategic plan that focuses on people, which prioritises sectors such as healthcare, mobility, sustainability, productive economy, the agri-food sector and public services, which will be built around the pivotal elements listed below:

- **Ecosystem:** promote a cross-cutting governance model that supports the development of a coordinated ecosystem of artificial intelligence connected to the rest of the world.
- **Research and innovation:** boost research and innovation by applying specific instruments and establishing synergies between public authorities, specialised research and innovation centres and organisations that use artificial intelligence intensively.
- **Talent:** create, attract and retain specialised talent that fosters the development of artificial intelligence solutions and transfer of knowledge to society, while training citizens and professionals of other sectors to be ready for its impact.
- **Infrastructure and data:** have the necessary infrastructures for the development of artificial intelligence and provide secure access to public and private data.

- **Adoption of artificial intelligence:** promote the incorporation of artificial intelligence to drive innovation in public administration and strategic sectors, including agri-food, healthcare and well-being, the environment, mobility, tourism, culture and industry.
- **Ethics and society:** promote the development of ethical artificial intelligence that respects applicable legislation, is compatible with our social and cultural norms and focuses on people.

Catalonia's Artificial Intelligence Strategy must be shared by all the bodies that form part of Catalan Public Administration, as well as the agents of the private sector, since artificial intelligence will lead to transformations and changes in fields that cross the borders of technology, research and investigation and include people, ethics, the employment environment, the legislative field, education, public services and the transformation of productive sectors.

6. Definitions

ACCIÓ	Catalan Agency for Business Competitiveness
ACIA	Catalan Association for Artificial Intelligence
AGAUR	Agency for Management of University and Research Grants
AI	Artificial Intelligence
AI4ALL	Artificial Intelligence for All
AI4EU	Artificial Intelligence for Europe
AQUAS	Catalan Agency for Healthcare Quality and Evaluation
BSC	Barcelona Supercomputing Center
CATNIX	Catalonia Neutral Internet Exchange Point
CCIA	International Conference of the Catalan Association for Artificial Intelligence
CDTI	Centre for the Development of Industrial Technology
CERCA	Research Centres of Catalonia
CIA	Central Intelligence Agency
CLAIRE	Confederation of Laboratories for Artificial Intelligence in Europe
COEINF	Official College of Computer Engineering of Catalonia
CSIC	Spanish National Research Council
DARPA	Defence Advanced Research Projects
DPC	Data Processing Centre
ELLIS	European Laboratory for Learning and Intelligent Systems
EurAI	European Association for Artificial Intelligence
GDP	Gross Domestic Product
HPC	High Performance Computing
ICFO	Institute of Photonic Sciences
ICT	Information and Communications Technology
IDEAI-UPC	Intelligence Data Science and Artificial Intelligence Research Center
IIIA	Artificial Intelligence Research Institute

PRACE	Partnership for Advanced Computing in Europe
R&D+i	Research, Development and Innovation
SDG	Sustainable Development Goals
SME	Small and Medium Enterprise
SWOT	Strengths – Weaknesses – Opportunities – Threats
STEAM	Science, Technology, Engineering, Art & Mathematics
YOMO	Youth Mobile Festival

Annexe I. Artificial intelligence in Catalan universities

Section 3.1.1 *Universities* identifies the main research groups or centres in different Catalan universities that develop artificial intelligence or work intensively with this technology. Detailed information regarding the implication of Catalan universities in AI development is provided below.

- **Polytechnic University of Catalonia (UPC)**

The UPC particularly stands out in AI field. Intensive research on artificial intelligence carried out by different groups of the UPC, some of which have been pioneers in this area for 40 years, led to the creation in 2017 of the specific research centre for Intelligent Data Science and Artificial Intelligence (IDEAI-UPC⁵⁸), which dedicates its efforts in resolving real problems related to the most immediate economic and industrial context.

This centre acts as an umbrella that joins competencies of a wide spectrum in this discipline and complementary approaches. It is important to point out that one of the groups that forms part of IDEAI, the Knowledge Engineering and Machine Learning Group (KEMLg⁵⁹), is one of the first AI research centres in Catalonia and it in 1985, it introduced the PhD in Artificial Intelligence, the first in Spain. Managed by the UPC, it led to the creation of the inter-university master's degree in artificial intelligence that from the beginning has been approached with a comprehensive perspective for Catalonia. The course is coordinated by the UPC, UB and URV and attracts a high number of international students.

The activity of the IDEAI-UPC research centre focuses on seven strategic lines of application: education; environmental and sustainability systems; inclusion, health and well-being; industry 4.0; digital society; economy; ethics and responsibility, with the intention to foster talent and innovation and address the ethical aspects surrounding the discipline.

To face the current challenges in these areas, the IDEAI-UPC research centre boosts research and technology transfer in the following fields of artificial intelligence and intelligent data science:

- Machine learning algorithms: this line of research defines the basic nature that brings together the different research groups. These systems have the capacity to learn and improve from experience, without having to be explicitly programmed. Work is carried out in fields such as the development of smart agents, analysis of social structure dynamics, construction of formal models to define norms and rules for ecommerce, design of information flow processes, reasoning based on temporal episodes, argumentation methods, hybrid methods between statistics and artificial intelligence, Bayesian networks, case-based reasoning, supervised and unsupervised machine learning techniques, identification and construction of knowledge models, knowledge representation, ontologies, social media, Semantic Web, web services, etc.

⁵⁸ <https://ideai.upc.edu/en>

⁵⁹ <https://kemlg.upc.edu/ca>

- Data science and data engineering: research on methodologies to find, process, analyse and extract relevant knowledge contained in data to support decision-making, among other features.
- Natural language and voice processing systems: this line centres on language processing, mainly written and spoken. The wide variety of problems related to language processing ranges from basic processing tasks (morphological, syntactical and semantic analysis) to applications of a higher level (information extraction, machine translation, automatic summarisation, question answering, dialogue systems, etc.). As regards voice, specialised techniques are used to recognise discourse from audio signals and conceptualise it with the previously described natural language tools, as well as construct verbal discourse using specialised databases. This is one of the few scientific fields that needs to develop specific resources for each language. IDEAI-UPC has resources in different Community and non-Community languages.
- Intelligent systems to support decision-making: this line of research works on the creation of algorithms, cognitive models and intelligent visualisation to effectively support decision-making by individuals and/or companies. The areas of application where IDEAI-UPC has experience include healthcare, environmental processes and systems, social and internet-based systems, and the industrial and business sector.
- Computer vision: with expertise in visual signal processing techniques to analyse and represent visual content, used in interaction [interfaces, smart-rooms), biomedical imaging and remote sensing, audio-visual production and security. The centre's experience in representation of content includes video compression and indexing in accordance with international standards, such as MPEG-4 and MPEG-7.
- Cognitive systems and computational thinking: this line of research is the result of combining the experience of the different groups that form part of the research centre in the development of computer systems capable of employing different forms of knowledge to think autonomously and/or semi-autonomously, often in social environments and in cooperation with other intelligent tools (including humans).
- Applications used to (i) identify and define real, more complex problems that require really intelligent solutions; (ii) achieve feedback in the developments performed; and (iii) interaction with the surrounding industrial and socio-economic network, thus adding value.

The UPC has created a complex network of international alliances with other universities, research institutions and companies that draw up new projects and support a high number of initiatives in which the word *collaboration* is the key element. A global and interconnected world that fosters

sharing knowledge and experiences is the background of the action of these alliances without borders.

- **Autonomous University of Barcelona (UAB)**

The UAB campus has two leading AI centres: The Artificial Intelligence Research Institute (IIIA⁶⁰) and the Computer Vision Center (CVC⁶¹).

The Artificial Intelligence Research Institute (IIIA) was founded in 1994 by a group of researchers from the Department of Artificial Intelligence of the Centre for Advanced Studies in Blanes (CEAB). The IIIA is a member of the CSIC, which is an 'aggregated entity' of the International Campus of Excellence (UAB-CEI) and has nearly 50 researchers and engineers. Annexe II describes this centre in greater detail.

El Computer Vision Center (CVC) was founded in 1995 by the government of Catalonia and the Autonomous University of Barcelona. It focuses on research in the field of computer vision and is a leader in the creation of knowledge in this field, with over 130 researchers, advanced hardware and software resources for computer vision. The centre covers an area of 2,000 m² dedicated to R&D of excellence. Annexe II describes this centre in greater detail.

The UAB also has a Department of Computer Science, which is in charge of teaching the subjects related to artificial intelligence (information technology, data engineering, computational mathematics), and is at the helm of the Inter-university Master's Degree in Computer Vision.

- **Pompeu Fabra University (UPF)**

Numerous research groups belong to the Department of Information and Communications Technologies at Pompeu Fabra University, including the artificial intelligence and machine learning group, COLT, WSSC, etc.

The group research covers several fields, including:

- Automated planning: is the model-based approach to intelligent behaviour, where conduct is not programmed or learned, but effectively derived from a model of the agent's goals, and in the way that the actions and sensors work in the world.
- Natural language: two groups (TRL-IULATERM and COLT) study natural language processing in the Department of Translation and Language Sciences at the UPF. TRL-IULATERM, Linguistic Resource Technologies - IULATERM, has specialised in text annotation and classification to extract linguistic data and develop machine-learning technology to construct linguistic resources: the set of necessary linguistic data to make applications for each language. It also focuses on the production and open publication of linguistic resources for Catalan, English

⁶⁰ <https://www.iiia.csic.es/ca/presentation>

⁶¹ <http://www.cvc.uab.es/?lang=ca>

and Spanish, among other languages, in different areas of application: health, legal, etc. COLT, Computational Linguistics and Linguistic Theory, develops methods for inducing representations of meaning based on data about how people use languages, also with machine learning technologies for language modelling. The group's project, AMORE: A distributional model of reference to entities (ERC Starting Grant 715154), studies modelling the phenomenon of linguistic reference and how to improve the inducement of relationships between concepts and extralinguistic context when understanding speech.

- Interactive machine learning: is a branch of machine learning concerned with sequential decision-making problems, where the goal is to design algorithms that optimize performance during the learning procedure itself, while facing an unknown and potentially non-stationary environment.
- Learning theory: is the science of analysing machine learning problems and algorithms, with the purpose of characterising the hardness of various learning scenarios and construct algorithms with demonstrable performance guarantees.
- Probabilistic graphical models: are graph-based representations to compactly encode probability distributions over high-dimensional spaces. The group focuses on how to efficiently answer queries (inference) and how to learn the graph structure from data (learning).
- Autonomous robotics: includes the development of complete software architectures as well as the creation of base methodologies and tools for new advanced features. The group combines reactive behaviour and motion planning with task planning, and use reasoning mechanisms to create robotics systems for challenges like RoboCup.
- Constraint satisfaction problems (CSP): these problems consist of a set of variables, a domain of values than can be taken by the variables and a set of constraints that specify the restrictions of the values that can be taken simultaneously by the variables. The task is to decide whether there exists an assignment of variables to values that satisfies all the constraints.
- The WSSC (Web Science & Social Computing) research group uses machine learning, big data and data science to address internet and social problems.

- **University of Barcelona (UB)**

The University of Barcelona identifies artificial intelligence as a strategic cross-cutting field. For this reason a multi-disciplinary cross-cutting structure was created to promote research, teaching, dissemination and transfer in advanced analytics, machine learning, data science and artificial intelligence that can strengthen the synergies between all associated areas of knowledge.

AI research at the University of Barcelona studies the multiple facets of artificial intelligence, from its computer-related aspect to its ethical, legal and social implications, as well as its neurological foundations. The main initiatives in this field are detailed below.

- **Algorithmic and computational perspective:** the UB has two specific groups for the mathematic, algorithmic and computational study of artificial intelligence: the Computer Vision and Machine Learning Group at UB, centred on machine learning and deep learning and their application to computer vision, and the Virtual Worlds, Visualization and Artificial Intelligence group, focused on virtual worlds, person-machine interaction and multi-agent systems. The members of the previous groups form part of the Institute of Mathematics of the University of Barcelona (IMUB) and the University of Barcelona Institute of Complex Systems (UBICS). In addition, theoretical aspects are studied that enable emerging behaviours in networks through interactions, as well as analytics in large networks and dynamic systems.
- **Legal and ethical perspective:** the legal perspective is studied by the Law, Intelligence and Robotics Research Group (DIAR) and the TransJus Research Group as part of its AI, big data and data protection research line. These groups address topics with a high social impact, such as the regulation of smart weapons or the social impact of automated processes in employment. As regards ethics, the Aporia Research Group in contemporary philosophy, ethics and politics studies the ethical implications of biotechnology and artificial intelligence. Related to both perspectives are the Bioethics and Law Observatory of the UB, specialised in the use of data, big data, data protection, highly protected and sensitive data, as well as the implications of new technologies based on data and artificial intelligence.
- **Philological and linguistic perspective:** the *Centre de Llenguatge i Computació* (Language and Computing Centre) at the University of Barcelona develops language technology resources, which include computing language models and natural language processing.
- **Neurobiological perspective:** the Institute of Neurosciences of the University of Barcelona, together with the Vision and Control of Action Group, BrainLab, Cognition and Brain Plasticity Unit, Neuropsychology Group, Attention, Perception and Acquisition of Language Research Group and the Event-Lab bring together researchers of different disciplines, from psychologists, neurobiologists and engineers, who seek to discover the brain mechanisms of cognitive functions, such as perception, attention, action and language, as well as its translation into computational models to study the brain and its activity.

Furthermore, artificial intelligence, machine learning and advanced data analytics have an **instrumental** presence in many study and research fields, where they are used extensively and therefore need to be studied and adapted to different domains. A brief reference is provided below to some of the initiatives that use these techniques, depending on the field of which they form part.

The **economic field** includes the Regional Quantitative Analysis Group, which uses machine learning tools to study econometric, seasonality and economic forecast models; the *Grup de Modelització Financera i Actuarial* (Actuarial and Financial Modelling Group), focused on fuzzy logic and mathematics for business, used for reinsurance, solvency and social security modelling, the *Grup de Risc en Finances i Assegurances* (Finance and Insurance Risk Group) that develops machine learning, modelling and advanced analytics models to detect and monitor financial risk and fraud detection.

In the **field of physics** there is a widespread use and adaptation of machine learning techniques and methods. Some of the groups and institutes that use these techniques are: the Institute of Cosmos Sciences (ICCUB), with projects as important as the Gaia Mission, whose goal was to create a map of the galaxy by way of the intelligent data analysis of telemetry and photometric processing. Other groups that centre their work on advanced analytics are the Experimental High Energy Physics Group, specialised in studying flavour physics (quark identification) and the Meteorology Group that, among others, uses predictive technology for meteorological networks, convective precipitation and solar radiation modelling.

In the **chemistry field**, the Institute of Theoretical and Computational Chemistry concentrates the groups that use computational and predictive tools to try and resolve problems that traditional chemistry is unable to resolve experimentally.

In the **biology field**, the Ecophysiology of Mediterranean Crops Research Group employs advanced analytics to study soil and crops with satellite imagery and UAV. The Integrative Systems Biology and Metabolomics Research Group provides computational and analysis services to better understand the causes and mechanisms of health, healthy aging and illnesses.

In relation to some research lines of the previous fields, the Water Research Institute brings together the work of different multidisciplinary groups that employ systems and algorithms to automatically count plants and crop organs, remotely quantify the effects of plagues and diseases, automatically identify diseases and support decision-making regarding crops.

The Geomodels Research Institute specialises in the development of modelling techniques to characterise and properly understand the systems and processes that determine the formation, localisation and quality of **geological** resources and reservoirs.

The Computational Biology and **Drug** Design Group applies machine learning, planning and search methodologies to discover drugs, predicting high-affinity interactions in macromolecular structures. Included under this umbrella are also initiatives that employ machine learning and data analysis tools in **food and** computational **gastronomy**.

The **archaeological** and archaeometry research team works on these image analysis techniques to locate sites, and the Centre for the Study of Provincial Interdependence in Classical Antiquity uses automatic inference and complex networks to reconstruct trading routes of ancient Rome.

In the **teaching field**, the University of Barcelona offers several specific programmes that are strongly related to artificial intelligence and machine learning; for example, the Inter-university Master's Degree in Artificial Intelligence, Master's Degree in Fundamental Principles of Data Science, Master's Degree in Statistics and Operations Research and the Master's Degree in Biomedical Engineering, among others. Furthermore, machine learning has a relevant presence in 15 master's degrees offered by the university. As regards bachelor's degrees, artificial intelligence, machine learning and advanced data analytics form part of 14 courses. The University of Barcelona offers two doctoral programmes that are directly related to the fundamental development of different areas of artificial intelligence: the PhD Program in Mathematics and Computer Science and the PhD in Engineering and Applied Sciences.

Ramon Llull University (URL)

Ramon Llull University concentrates research and study of artificial intelligence in the La Salle Engineering School, where the Electronics, Telecommunications and Data Analysis (GR-SETAD) and the Intelligent Systems (GRSI) research groups (1998-2014) carry out research on artificial intelligence, data science, machine learning, data mining, data analysis, knowledge-based systems, especially applied to medicine and education.

In the same context is the Data Science for the Digital Society (DS4DS) research group, created in 2017 with the aim to provide a common and cross-cutting space for the different fields of knowledge by collecting continuing with the work of previous researchers with extensive experience in artificial intelligence and data science. Its main pivotal elements are:

- Artificial intelligence, machine learning and data analysis applications. The group wants to obtain a cross-sectional view of the problems related to the use of data that use artificial intelligence, machine learning and statistical techniques and searches for their potential effects and assets applied in different domains.
- Data analysis for high energy physics. A unique field of application is in the Big Science framework, through the collaboration in LHCb, one of the four main detectors of the LHC at CERN, which contributes and develops new methods for the data analysis. Domain: HEP (High-Energy Physics).
- Data analysis for business management. The wishes to obtain a comprehensive view of data-use problems, particularly concerning matters like smart living, smart business and smart university. [review wording]

Ramon Llull University also has different research groups that apply artificial intelligence techniques to their areas of knowledge.

Judgements and Decisions in the Marketplace (JUICE) is a consolidated research group that works in decision-making in the marketing and artificial intelligence fields. JUICE aims to understand consumers, customers and companies' decisions and use artificial intelligence to capture the

complexity of these decisions and interactions. The group is made up of 12 researchers from ESADE Business School and there are currently five PhD candidates and two postdoctoral researchers. The JUICE research group is attached to the ESADE Institute for Data-Driven Decisions (ESADEd3).

- **University of Girona (UdG)**

The University of Girona has different research groups involved in artificial intelligence, of which the following are particularly significant:

eXiT is a research group of the Institute of Computer Science and Applications of the University of Girona that participates in national and international research and transfer projects. Its main activity focuses on the application of the principles of artificial intelligence and automatic learning to support decision-making processes. This research is carried out mainly in two areas of application: health and smart cities. The members of the group participate in the academic activities of the inter-university doctoral programme in Biocomputing.

ViCOROB is the Computer Vision and Robotics Research Group at the University of Girona. Founded in 1993, it is now recognised as a consolidated research group by the government of Catalonia and also has held the TECNIO quality label in technology transfer since 2008. ViCOROB aims to be a leading name at home and abroad in the field of robotics, intelligent systems and perception, with emphasis on the group's own research. The team that makes up the group is structured into four research labs and is complemented by its own technical and administrative staff. The three labs are:

- Image analysis and pattern recognition and 3D perception
- Underwater vision and robotics
- UdiGitalEdu: ICT and education

ARLAB is the research group of the University of Girona that focuses on artificial intelligence applied to recommender systems and robotics. ARLAB forms part of the consolidated research group, Communications and Intelligent Systems, and the person in charge belongs to the IliA. ARLAB was founded in 2002 and has held the TECNIO technology-transfer label since 2004. In TECNIO, ARLAB is known as EASY. The centre is highly active as regards basic research and research focused on industry and technology transfer. Work is performed in the following areas:

- Rescue robots
- Digital preservation
- Virtual currencies
- Social media data analysis

The Laboratory of Chemical and Environmental Engineering (LEQUIA) is a research group of the University of Girona, recognised as a member of TECNIO and a consolidated research group of the government of Catalonia. It develops eco-innovative water solutions within the framework of national and international R&D+i projects, working in collaboration with other academic agents

and technology transfer agreements with private companies and public institutions of the sector. Working in this environment, over 25 years ago the group started collaborating with the KEMLG Group of the UPC in the application of AI tools to water management. The collaboration is considered the first of its kind in Europe and is basically centred on the design and operations of wastewater treatment plants where environmental decision support systems (EDSS) have been developed, integrating advanced control systems, mathematical models and AI techniques, which have led to a considerable number of publications in specialised magazines, agreements and even resulting in the joint creation of a company, Sisltech S.L. This experience is has recently spread to the drinking water field and the definition and construction of ontologies for a comprehensive water cycle management, using machine learning tools.

- **University of Lleida (UdL)**

The University of Lleida has several departments dedicated to AI research. One of the most significant is GREIA, which was established in 1999 as a multidisciplinary group. It focuses on providing industry with concurrent engineering solutions related to the fields of energy and construction engineering, obtained through research, technology transfer and training. The main lines of research are electric energy and construction engineering.

The Artificial Intelligence Research Group at the University of Lleida is made up of members of the Computer Science Department. At present, research is focused on the following areas.

- Argumentation: propositional logic, technological applications and integration with fuzzy logic programming languages;
- Constraint programming: modelling, practical complexity, distributed CSP, weighted CSP and connections with satisfaction.
- Fuzzy logic programming: integration of logic and fuzzy logic programming languages, and uncertainty handling formalism, such as possibilistic logic.
- Satisfiability: design, analysis, implementation and evaluation of algorithms to deal with SAT, Max-SAT and QBF problems, for both Boolean formulas in CNF and many values, efficient coding, logic calculations, traceable problems, phase transitions, local searching and learning. An argumentative approach to discover relevant opinions on Twitter with probabilistic valued relationships.

- **Rovira i Virgili University (URV)**

The research team at the Rovira i Virgili University, in Tarragona, was formed in 1998. It focuses on machine learning and knowledge representation applied to applied to medicine. The main technologies of interest are intelligent data analysis, machine learning, representation of medical knowledge for making clinical decisions, medical information and medical know-how.

At present, from a medical perspective, they are working on integrating knowledge in order to treat patients with multi morbidities, defining the length of time patients will be in intensive care units before they are discharged, analysing data to predict breast cancer survival and are studying ways to improve treatment of acute respiratory distress syndrome.

With this purpose it collaborates with the ICU of Joan XXIII University Hospital (Tarragona), Accident and Emergency department of Hospital Clínic of Barcelona and University Hospital Sant Joan de Reus. The Artificial Intelligence Research Group at Rovira i Virgili University, Tarragona, performs an important disseminating activity, particularly the organisation of the International Workshop on Knowledge Representation for Healthcare (held annually for the past 10 years), the annual edition of a Springer LNAI volume on knowledge representation for healthcare, the coordination of research projects and organisation of seminars on technological criteria for efficiency and sustainability. They are currently organising the International Conference on Artificial Intelligence in Medicine (AIME 2019).

The Intelligent Technologies for Advanced Knowledge Acquisition Group (ITAKA) of Rovira i Virgili University is one of the government of Catalonia's consolidated research groups. Its research lines can be classified into three large areas: semantic management of knowledge, decision-making support systems and computer vision.

In the first field, they have worked on automatic ontology learning, semantic search, and knowledge extraction and representation of structured, semi-structured and textural sources. They are currently focusing their research in this field on the semantic analysis of textual information, including feeling analysis. The results of the investigation are being applied in the field of communication for promoting tourist destination brands (analysing the transmission and reception of emotional values on social media).

As regards decision-making support systems, the ITAKA Group has been working on intelligent data analysis (especially including classification and machine learning methods), learning and dynamic management of user preferences, development of new information aggregation operators, improvement of multi-criteria decision-making methods based on preference relations and recommender systems. In relation to the latter, they have developed recommendation systems for tourist activities in the Tarragona area, together with the *Parc Científic i Tecnològic de Turisme i Oci* (Science and Technology Park for Tourism and Leisure of Catalonia). Working in collaboration with the Pere Virgili Institute, they have applied intelligent data analysis techniques to build a system capable of personally predicting whether a diabetic patient has a risk of suffering diabetic retinopathy. This system, which received the prize for Social Impact of Research, awarded by the URV, will help screen these patients adequately and make better use of available resources.

In the field of computer vision, they are developing systems that help detect tumours in different types of medical images, especially in mammograms. They are applying both traditional computer vision techniques and new methods based on deep convolutional neural networks. These kinds of networks are being applied to retinography analyses, so as to build a comprehensive management system of diabetic patients that uses personal and clinical data, as well as the result of the analysis of fundus photography.

Annexe II. Research and innovation centres that work with artificial intelligence

Section 3.1.2, *Research and innovation centres*, identifies the research and technology centres of Catalonia's knowledge ecosystem that work with artificial intelligence. Detailed information is provided below about the AI development activity performed in each centre.

- **Artificial Intelligence Research Institute (IIIA-CSIC)**

The Artificial Intelligence Research Institute (a member of TECNIO) was founded in 1994 by a group of researchers from the Department of Artificial Intelligence of the Centre for Advanced Studies in Blanes (CEAB). It is one of Europe's renowned AI research centres. It is made up of about a hundred doctors who work in this field, some of whom are teachers in nearly all the Catalan universities. As a result, it is at the core of the Catalan AI ecosystem. The CEAB's artificial intelligence department has been researching this field since 1985.

Research in the IIIA focuses on diverse well-defined sub-areas within the field of artificial intelligence (machine learning systems, multiagent systems, and reasoning and logic), it prevents different topics from spreading to other areas, it maintains a balance between basic and applied research, and dedicates considerable effort in training doctors and technology transfer. The Technology Development Unit supports its research activities and can increase its technology transfer capacity by channelling contacts with companies. In particular, it maintains strong ties with three spin-offs it has created: iSOCO, STRANDS and CogniCOR. The IIIA belongs to the CSIC, which is an 'aggregated entity' of the UAB-CEI. The IIIA plays an important role in different master's and doctoral degree offered by Catalan universities.

The main strategic research areas of the IIIA are described below:

- Machine learning systems. The activities in this line of research focus on three main subjects: case-based reasoning, machine learning applied to robotics and data privacy (particularly in data mining, preserving privacy).
- Multiagent systems. The activities of this line of research focuses on computer models of business negotiation, control, organisation of open multiagent systems and software engineering addressed to agents.
- Reasoning and logic. The activities in this line of research focus on basic research in fuzzy logic, formulisation and resolution of constraint-based problems and SAT problems, complementing and covering different aspects of the fundamental problem of modelling reasoning capacity in machines.

- **Computer Vision Center (CVC)**

Computer Vision Center (member of CERCA and TECNIO) is a non-profit research centre with its own legal status, established in 1995 by the government of Catalonia and the Autonomous University of Barcelona. Its mission is to carry out cutting-edge research in the field of computer vision to obtain the highest international impact, promoting technology and knowledge transfer to industry and society. The CVC strives to prepare and train researchers at the highest European level. The centre has positioned itself as a specialist in the field of computer vision and is considered a leader in the creation of knowledge for society. The CVC performs state-of-the-art research in the following areas: medical imagery analysis, object recognition, document analysis, interpretation of images, colour and texture, vision systems in UAVS, visual perception, industrial vision, indexing and multimedia recovery; interpretation of video surveillance images; interactive 3D viewing; and augmented reality. The centre offers highly specialised technical consulting, training and transfer of highly qualified people for industry, as well as technology transfer developed according to companies' specifications. This combination of talent and effort results in unequalled computer vision algorithms recognised by the scientific community. In addition, the researchers' entrepreneurial spirit promotes innovation and gives added value to the created knowledge and transfers real solutions for society as a whole. As a result of the world-renowned Master's Degree in Computer Vision and Artificial Intelligence, the CVC trains brilliant young students, who will become the future leaders in computer vision research and development.

The CVC has transferred its knowledge of computer vision to several sectors, including the medical and pharmaceutical industries (to international companies like Given Imaging LTD and Boston Scientific, in the fields of minimally invasive colonoscopy procedures and cardiology), automotive industry (SEAT, Volkswagen, Ficosa, through ADAS systems), industrial sector (Lear Corp., Berger Group, Continental, B/Braun, through advanced industrial inspection systems) among others. In many cases it has also obtained joint patents between the centre's researchers and companies, as well as doctoral theses and the launch of leading products onto the market.

- **Barcelona Supercomputing Center (BSC)**

El Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS) is a consortium formed by the ministry of Business and Knowledge of the government of Catalonia, the UPC and the Spanish ministry of Science, Innovation and Universities, and is one of Catalonia's largest research centres with over 500 researchers distributed into four departments: Computer Sciences, Life Sciences, Earth Sciences, and Computer Applications in Science & Engineering. To give an idea of the centre's capacity to attract competitive public funds, the BSC has 105 H2020 projects underway –39 were started in 2018– and 11 are coordinated in the centre. As a whole, BSC-CNS is the Catalan institution (including universities and companies) that receives the most funds from the European framework research programme, Horizon 2020. In addition, artificial intelligence is widely used by many other groups, especially in the engineering and life sciences fields.

At the beginning, AI research was performed in different places, so in 2018 the strategic decision was taken to concentrate all the work in the BCS. The High Performance Artificial Intelligence (HPAI) group was created as part of the Computer Science department, with the aim of supporting other departments by using artificial intelligence in their investigations. There are currently 50 researchers in the BCS that study the field or habitually use their own AI tools. At present, the BCS is responsible for the artificial intelligence in four H2020 projects.

The two groups that perform AI research in the centre are the High Performance Artificial Intelligence (HPAI) group, which focuses on researching and applying AI techniques using HPC tools infrastructures, and the Emerging Technologies for Artificial Intelligence (TEAI) group, which carries out basic research in a wide range of areas of artificial intelligence, such as deep learning (DL) and reinforcement learning, always using supercomputing platforms.

The centre forms part of the 30 Digital Innovation Hubs which focus on artificial intelligence and were selected by the UE. As a result, it receives mentoring and coaching in business development, financing and innovation management, so as to develop its projects and transfer its knowledge and outputs to SMEs in Catalonia.

- **Eurecat, Centre Tecnològic de Catalunya**

Eurecat, the Catalan Technology Centre (member of the TECNIO network) has the mission of boosting applied research on technology-based solutions that can be transferred to the business network, besides improving existing products, processes or services. With over 600 professionals and an annual turnover of around €50 million, it works with more than 1,000 companies through applied R&D+i, diverse technological services, highly specialised training, technological consulting and dissemination events for professionals in different sectors. The centre has operational establishments throughout Catalonia and is currently participating in 160 large joint national and international projects. It has 73 patents and seven spin-offs (data from 2018).

It has a multidisciplinary team made up of scientists and technologists who work in three large areas: industrial technologies, biotechnology and digital technologies. Within digital specialisations, data analysis and artificial intelligence have a prominent role due to their multisector and cross-cutting nature, as well as their capacity to combine strictly digital knowledge with different domains of application. As a result, Eurecat is developing projects applied to sectors that include the manufacturing industry, tourism, health, mobility, safety and social sciences, in which different technologies are deployed in the fields of artificial intelligence, machine learning, deep learning, reinforcement learning, computer vision, NLP, etc. In its technological definition, Eurecat has identified a number of strategic lines in which artificial intelligence and data analysis play a major role, specifically artificial intelligence for industrial applications, advanced robotics, medical devices and personalised nutrition.

Eurecat has managed the Centre of Excellence in Big Data, in Barcelona (CoE Big Data) since 2015. At that time, it was a pioneering initiative also promoted by the government of Catalonia and

Barcelona City Council, with the mission of developing knowledge applied in the field of data analytics and especially boosting data economy in the country's business sector. The CoE Big Data holds the i-Space label awarded by the Big Data Value Association (there are a total of 10 i-Spaces in Europe) and has its own cloud computing infrastructure to perform research in this field (DATURA, IaaS for the data analysis service with 4TB of RAM, 64TB of memory that implements a Red Hat Openstack Platform). An investment is planned for 2019 that will increase this platform with the aim of developing AI projects.

- i2CAT Foundation

The i2CAT Foundation (member of CERCA and TECNIO) is an applied research institution that focuses its work on the Internet and digital technologies. It is backed by 13 years of experience in multiple national and international R&D+i projects; it heads research lines in fixed and mobile network architectures, wireless sensor networks, big data and content-based multimedia technologies. The research carried out in i2CAT aims to develop new products, services and applications related to eHealth, Smart Cities & Smart Regions, Advanced Manufacturing and Digital Social Innovation. The government of Catalonia, under the leadership of the Secretariat for Digital Policy, has a direct and majority interest in the Foundation. It acts in the following fields: international R&D, strategic country-wide projects, and transfer and services to companies.

Ten years' experience defining and executing R&D projects, working in collaboration with European and international partners, has created knowledge that i2CAT takes to the country's business network and its citizens.

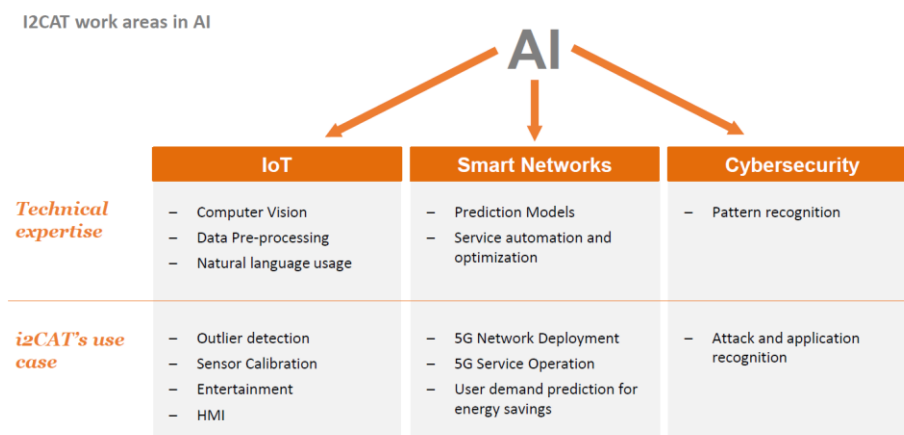


Figure 17. i2CAT's areas of action in artificial intelligence

Source: i2CAT

- **CIMNE**

The aim of CIMNE (a member of CERCA and TECNIO) is the development of numerical methods and computational techniques for advancing knowledge and technology in engineering and applied sciences. CIMNE's headquarters are in the North Campus of the UPC, in Barcelona. The research and technology development activities performed in CIMNE cover a wide spectrum of topics, ranging from classical engineering fields such as civil, mechanical, environmental, naval, marine, telecommunications and biomedicine, information technology and applied sciences, including computational physics, nature, social and economic sciences and the multimedia sector and reaching matters related to artificial intelligence and machine learning applied to decision-making support systems.

- **CIT UPC**

The CIT UPC (member of CERCA and TECNIO) is the Innovation and Technology Centre at the UPC, made up of 20 research and investigation centres. Its purpose is to improve business competitiveness through the transfer and commercialisation of technological knowledge. The CIT UPC includes the MCIA, specialised in mechatronic and energetic systems; the CREB, specialised in biomedical research, and the DAMA, specialised in processing large volumes of data.

- ***Institut de Robòtica i Informàtica Industrial -IRI (Institute of Robotics and Industrial Computer Science)***

The *Institut de Robòtica i Informàtica Industrial* (member of TECNIO), is a university institute jointly owned by the CSIC and the Polytechnic University of Catalonia (UPC). The centre offers expertise and technological capacity in different areas of robotics, computer vision, artificial intelligence and automatic control, among others. The IRI transfers knowledge in human-centred robot systems, design and construction of innovative robot mechanisms, the application of innovative computer vision algorithms, AI systems and energy-efficiency systems, etc.

- **Easy**

Centre Easy (member of TECNIO) has been working for over 15 years in basic research on artificial intelligence combined with technology transfer in many applied research projects. It specialises in artificial intelligence and MachCrowd (machines + crowds), smart digital technologies and their transfer to industry. As regards artificial intelligence and Machcrowd, social research consists of automating some aspects of interactions between users with the purpose of improving and accelerating the results. In relation to smart digital technologies, the centre is an expert in virtual currencies and digital preservation. Centre Easy offers the only official master's degree in smart cities in Europe.

- **La Salle R&D**

La Salle R&D (member of TECNIO) is a research, innovation and consulting centre attached to Ramon Llull University. The centre has a long history and extensive experience developing projects for large companies and start-ups, and even collaborates in scientific and international projects of

great importance. The current research lines are related to ICT, decision-making support systems, electronics, human-computer interaction, security and networking. Its research is aimed towards offering society technological solutions to improve services, especially in the fields of health and smart cities. AI research includes working on human-computer interaction by means of computer vision and face and gesture recognition, data analysis, machine learning, signal processing, image processing, interactive bots, etc.

- **DATASCIENCE@UB**

DATASCIENCE@UB (member of TECNIO) is a research and knowledge-transfer centre in the big data and advanced data analysis fields. It comprises two groups of the UB that belong to the faculties of Mathematics and Computer Science, and Physics: the research group for Computer Vision and Machine Learning at the University of Barcelona, which focuses on the basic principles of algorithms for machine learning and its applications in health, finance and marketing, and the Complexity Lab Barcelona (ClabB), specialised in the study of complex systems using ideas from statistical physics and complex networks.