



JRC TECHNICAL REPORT

AI Watch 2019 Activity Report



EUR 30254 EN

This publication is a Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication. For information on the methodology and quality underlying the data used in this publication for which the source is neither Eurostat nor other Commission services, users should contact the referenced source. The designations employed and the presentation of material on the maps do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Contact information

Email: EC-AI-WATCH@ec.europa.eu

EU Science Hub

<https://ec.europa.eu/jrc>

JRC121011

EUR 30254 EN

PDF

ISBN 978-92-76-19515-3

ISSN 1831-9424

doi:10.2760/007745

Luxembourg: Publications Office of the European Union, 2020



The reuse policy of the European Commission is implemented by the Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39). Except otherwise noted, the reuse of this document is authorised under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence (<https://creativecommons.org/licenses/by/4.0/>). This means that reuse is allowed provided appropriate credit is given and any changes are indicated. For any use or reproduction of photos or other material that is not owned by the EU, permission must be sought directly from the copyright holders.

All content © European Union, 2020, except: Cover image © Sdecoret©AdobeStock, 2018 Peshkova©AdobeStock, 2018 (and unless otherwise specified).

How to cite this report: Desruelle, P. (ed.), Delipetrev, B., Tsinaraki, C., Nepelski, D., Gomez, E., Martinez-Plumed, F., Misuraca, G., De Prato, G., Fullerton, F., Craglia, M., Duch Brown, N., Nativi, S., Van Roy, V., *AI Watch 2019 Activity Report*, EUR 30254 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19515-3, doi:10.2760/007745, JRC121011.

Contents

- Abstract.....5
- Foreword.....6
- Acknowledgements7
- Executive summary.....8
- 1 Introduction – Why a European Artificial Intelligence observatory?.....11
- 2 What has been done until now to build the AI Watch observatory12
 - 2.1 AI Watch Steering Group.....12
 - 2.2 AI Watch team.....12
 - 2.3 Preliminary Dialogue with External Organisations.....13
 - 2.3.1 OECD13
 - 2.3.2 The German Observatory for AI13
 - 2.3.3 The AI Observatory of the Politecnico di Milano13
 - 2.3.4 AI Laboratory of the Jozef Stefan Institute in Slovenia13
 - 2.3.5 Industry associations.....13
- 3 Understanding Artificial Intelligence14
- 4 Understanding the Evolution of Artificial Intelligence Technologies.....15
 - 4.1 AI History Timeline15
 - 4.2 Understanding current evolution and trends of AI technologies: the AI Watch “*Aicollaboratory*”15
 - 4.2.1 References for the *Aicollaboratory*17
 - 4.2.2 Report: “AI Watch: Methodology to Monitor the Evolution of AI Technologies”18
- 5 Understanding the Worldwide Landscape of AI19
 - 5.1 On-line AI Landscape Dashboard.....19
 - 5.2 Report: “TES analysis of AI Worldwide Ecosystem in 2009-2018”20
- 6 Measuring Development and Impact of AI.....21
- 7 Understanding AI Policy Developments in the EU Member States.....22
 - 7.1 National strategies on Artificial Intelligence.....22
 - 7.2 Estimating AI investments in the EU Member States.....23
- 8 Understanding Impact of AI on the Economy.....26
 - 8.1 Take up in selected sectors of the economy, in selected regions26
 - 8.2 Participation in meetings26
 - 8.2.1 Science Meets the European Parliament on AI, 5-7 February 201926
 - 8.2.2 Geospatial World Forum, Amsterdam 1-4 April 2019.....26
 - 8.2.3 High level conference on AI in aviation, 23 May 2019.....27
 - 8.2.4 Futures workshop on AI in legal and professional services, London 14 July 2019.....27
 - 8.2.5 AI in critical industrial applications project workshop, 23 September 2019, Brussels27
 - 8.3 Partnerships with industry associations.....27
 - 8.4 Partnerships with Regional Authorities.....28

8.5	Evolution of the European Market Shares in Robotics	28
8.6	Monitoring Standardisation in AI	29
9	Understanding use and impact of AI in the public sector	30
9.1	Overview of AI use in public services in the EU	30
9.2	Outlining a methodology for assessing impacts of AI in public services	30
9.3	Peer learning with and among Member States on AI for the public sector	31
9.4	Report “Artificial Intelligence in public services - Overview of the use and impact of AI in public services”	31
10	Understanding Impact of AI on Human Behaviour (HUMAINT)	32
10.1	Algorithms for decision making in criminal justice	32
10.2	The occupational impact of AI	33
10.3	Social robots and child development	34
10.4	The impact of AI on music, creativity and culture	34
10.5	Transversal HUMAINT activities	34
10.6	Key HUMAINT publications	34
10.7	HUMAINT Project team	35
11	Understanding impact on AI on Society	36
11.1	Digital skills	36
11.2	Data Governance Models (DIGITRANSCOPE)	37
11.2.1	Emerging Models of Data Governance in the Age of Datafication	37
11.2.2	Typology of Data Governance Models	37
11.3	Participation in the JRC Collaboration with leading Science Centres & Museums	38
12	Conclusions	39
	List of figures	40
	List of tables	40
	Annex 1: AI Watch publications	41
	Reports	41
	On-line	41
	Annex 2: AI Watch tasks and activities, and their leaders	42

Abstract

This report provides an overview of AI Watch activities in 2019. AI Watch is the *European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe*. As part of the European strategy on AI, the European Commission and the Member States published in December 2018 a “Coordinated Plan on Artificial Intelligence” on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation. AI Watch was launched in December 2018. It aims to monitor European Union’s industrial, technological and research capacity in AI; AI national strategies and policy initiatives in the EU Member States; uptake and technical developments of AI; and AI use and impact in public services. AI Watch will also provide analyses of education and skills for AI; AI key technological enablers; data ecosystems; and social perspective on AI. AI Watch has a European focus within the global landscape, and works in coordination with Member States. In its first year AI Watch has developed and proposed methodologies for data collection and analysis in a wide scope of AI-impacted domains, and has presented new results that can already support policy making on AI in the EU. In the coming months AI Watch will continue collecting and analysing new information. All AI Watch results and analyses are published on the AI Watch public web portal (https://ec.europa.eu/knowledge4policy/ai-watch_en). AI Watch welcomes feedback. This report will be updated annually.

Foreword

This report is produced in the context of AI Watch, the European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe, launched in December 2018.

AI has become an area of strategic importance with potential to be a key driver of economic development. AI also has a wide range of potential social implications. As part of its Digital Single Market Strategy, the European Commission put forward in April 2018 a European strategy on AI in its Communication "Artificial Intelligence for Europe" COM(2018)237. The aims of the European AI strategy announced in the communication are:

- To boost the EU's technological and industrial capacity and AI uptake across the economy, both by the private and public sectors
- To prepare for socio-economic changes brought about by AI
- To ensure an appropriate ethical and legal framework.

Subsequently, in December 2018, the European Commission and the Member States published a "Coordinated Plan on Artificial Intelligence", COM(2018)795, on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation.

AI Watch monitors European Union's industrial, technological and research capacity in AI; AI-related policy initiatives in the Member States; uptake and technical developments of AI; and AI impact. AI Watch has a European focus within the global landscape. In the context of AI Watch, the Commission works in coordination with Member States. AI Watch results and analyses are published on the AI Watch public web portal (https://ec.europa.eu/knowledge4policy/ai-watch_en).

From AI Watch in-depth analyses we will be able to understand better European Union's areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education, and society.

AI Watch is developed by the Joint Research Centre (JRC) of the European Commission in collaboration with the Directorate-General for Communications Networks, Content and Technology (DG CONNECT).

This report provides an overview on development of AI Watch, essentially covering its 2019 activities. Most of the publications resulting from 2019 AI Watch activities were published in the first months of 2020. A list of published AI Watch reports is available in Annex. The last sections of this report describe several JRC activities on AI that are closely related to AI Watch (e. g., HUMAINT, Digital Skills, Digitranscope). This report will be updated annually.

Questions and comments on AI Watch can be sent to EC-AI-WATCH@ec.europa.eu

Acknowledgements

We are grateful to the external experts on AI who have supported our work in 2019 and notably to Prof. Barry O'Sullivan (University College Cork) and to Prof. José Hernández-Orallo (Universitat Politècnica de València). We warmly thank the national representatives of the 28 EU Member States in 2019, part of the AI Watch Steering Group, who provided feedback on our early results and are helping us increasing the value of AI Watch analyses and results for national policy makers.

We are also extremely grateful to our colleagues in DG CONNECT. First, to those who had the original idea in 2018 of developing an observatory of AI developments in the EU, in particular to Juha Heikkilä and Cecile Huet, and to the colleagues who closely collaborate with JRC on the different activities of AI Watch, in particular to: Antonio Puente, Davide Valitutti, Eric Badiqué, Irina Orsich, Mariana Popova, and Maikki Sipilinen.

Finally we would like to thank our colleagues from the JRC Digital Economy Unit. Starting by Alessandro Annoni, our former Head of Unit, who played a key role in the setup and launch of AI Watch, and the colleagues who have contributed, together with the report authors mentioned below, to tasks and activities described in this report, notably: Alessandro Dalla Beneta, Colin van Nordt, Fiammetta Rossetti, Francesco Pignatelli, Georgios Alaveras, Maciej Sobolewski, Melisande Cardona, Miguel Vazquez-Prada Baillet, Montserrat Lopez Cobo Jiri Hradec, Riccardo Righi Sarah de Nigris, Sofia Samoili, and Uros Kostic.

Authors

The co-authors of this report are: Blagoj Delipetrev, Chrisa Tsinaraki, Daniel Nepelski, Emilia Gomez, Fernando Martinez-Plumed, Gianluca Misuraca, Giuditta de Prato, Karen Fullerton, Massimo Craglia, Nestor Duch Brown, Paul Desruelle (overall editor), Stefano Nativi and Vincent van Roy, all from the Digital Economy Unit of the JRC.

Executive summary

This report provides an overview of AI Watch activities in 2019. AI Watch is the *European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe*. AI Watch was launched in December 2018, it is developed by the Joint Research Centre (JRC) of the European Commission in close collaboration with the Directorate-General for Communications Networks, Content and Technology (DG CONNECT).

Policy context

AI has become an area of strategic importance with potential to be a key driver of economic development. AI also has a wide range of potential social implications. As part of its Digital Single Market Strategy, the European Commission presented in April 2018 a European strategy on AI in its Communication "Artificial Intelligence for Europe" COM(2018)237. The aims of the European AI strategy announced in the communication are:

- To boost the EU's technological and industrial capacity and AI uptake across the economy, both by the private and public sectors
- To prepare for socio-economic changes brought about by AI
- To ensure an appropriate ethical and legal framework.

Subsequently, in December 2018, the European Commission and the Member States published a "Coordinated Plan on Artificial Intelligence", COM(2018)795, on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation.

More recently, on 19 February 2020, the Commission unveiled its vision for a digital transformation that works for everyone. This includes a White Paper proposing a framework for Artificial Intelligence based on excellence and trust.

One particular challenge is the extremely fast development of AI. Policymakers are struggling to monitor the AI landscape and analyse its uptake and impact to know where and how their intervention could tip the balance towards desirable outcomes for society, hence the essential role that AI Watch can play to support policy making on AI in the EU.

AI Watch scope and key objectives

From AI Watch in-depth analyses we will be able to understand better European Union's areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education, and society.

More specifically, AI Watch aims to monitor European Union's industrial, technological and research capacity in AI; AI national strategies and policy initiatives in the EU Member States; uptake and technical developments of AI; and AI use and impact in public services. AI Watch also provide analyses of education and skills for AI; AI key technological enablers; data ecosystems; and social perspective on AI. AI Watch has a European focus within the global landscape. AI Watch works in coordination with Member States. For this purpose, a steering group composed of Member States representatives was established in 2019.

Main AI Watch outcome, so far

The present report describes first how we organised ourselves in 2019, and then presents the different activities of AI Watch and several JRC activities on AI that are closely related to AI Watch.

A mandatory first step before starting analysing AI and its impact is to understand what AI is. AI Watch therefore developed in its first year an **operational definition of AI** to be adopted for the monitoring activities of AI Watch, and presented in its report "Defining Artificial Intelligence – Towards an operational definition and taxonomy of artificial intelligence." This definition will be updated in 2020 taking into account the received feedback.

In order to understand the evolution of AI Technologies, AI Watch developed an **AI history timeline** that includes selected important AI breakthroughs since the 1950's. This timeline is open to additional contributions. AI Watch also developed a data-driven framework to collect and explore data about AI results, progress and ultimately capabilities, the **Aicollaboratory**. The on-line platform is populated in an open and

collaborative fashion, facilitating cross-comparison and reproducibility. We can extract from this collaborative platform qualitative information related to the state of the art, challenges and trends of AI research and development.

AI Watch developed in 2019 an overview and analysis of the **worldwide AI landscape**. The on-line AI landscape dashboard provides several perspectives on areas of specialisation (e.g., Machine Learning, Autonomous vehicles, etc.) and on industry and R&D. In a specific AI Watch report, companies, universities, research institutes and governmental authorities with an active role in AI are identified and analysed in an aggregated fashion, and collaborations between firms, research institutions are analysed. This report will be updated in 2020.

AI Watch also aims to develop a dashboard of **AI indicators and metrics** relevant for policymaking. As a first step, a methodology report was produced, describing how to identify a set of indicators suitable to provide a comprehensive and balanced overview of the various topics addressed by AI Watch, in order to allow for comparison among countries and regions in the evolving international economic, social, industrial and research landscape of AI.

One of the key priorities of the December 2018 Coordinated Plan on AI is to encourage Member States to develop their national AI strategies by the end of 2019 outlining investments levels and implementation measures. AI Watch collected and analysed in 2019 **national strategies on AI**. For this purpose, AI Watch developed an analytical framework covering policy initiatives on: human capital, R&D and innovation, networking, regulation, and infrastructure. This framework enables Member States to compare their strategy and to identify areas for strengthening synergies and collaboration. The AI Watch report on: “National strategies on Artificial Intelligence: A European perspective in 2019” will be updated in 2020. In this context, AI Watch works in collaboration with the OECD AI policy Observatory (OECD.AI).

In spite of a large interest in AI, among many open questions around this promising technology, the question of what is the actual level of investments in AI is particularly difficult to answer. AI Watch developed in 2019 an original and comprehensive methodology to estimate AI investments and applied it to assess **AI investments in the EU** in 2018. We welcome feedback on the methodology documented in the AI Watch report “Estimating investments in General Purpose Technologies: The case of AI Investments in Europe”. This analysis will be updated annually.

AI as a general-purpose technology can rapidly spread across industry sectors and yield strong positive growth effects. The key AI Watch activity in 2019 on understanding **impact of AI on the Economy** was the preparation of a methodology to monitor the uptake and impacts of AI applications across the economy, including geographical and sector comparison. The methodology is designed to:

- Assess current state of AI adoption in different sectors to act as benchmark for future comparison,
- Identify within-sector variations across geographies and areas of application,
- Deliver comparative results across sectors, and agreed indicators for EU-wide assessment,
- Identify cross-sectorial issues, and specificities of each sector,
- Identify a number of representative case studies to analyse in further detail at regular intervals and act as “probes” of change over time.

The **combination of AI and robotics** gives birth to ‘artificially intelligent robots’ that carry important socio-economic implications. Robotics is a field in which Europe must keep its competitive advantage. AI Watch developed in 2019 various activities to respond to this need and to support policy makers. The AI Watch methodology report ‘Tracking the EU robotics market shares: data and methodology’ presents an overview of literature and of policy reports in the field of robotics, sources of data, and discussed methodological challenges, such the identification and quantification of “AI-enhanced” robots.

Another important goal of AI Watch is to propose a basic framework for analysing the **use and impact of AI in public services**, in order to understand impact of AI on government. The focus in the first year of AI Watch was i) to provide an overview of the use of AI in public administration and in the delivery of public services in EU Member States, and ii) to start developing a proposal for a methodology to assess the potential impacts of the adoption of AI in public service provision. Public information was collected on use of AI in public services in EU Member States and preliminary case studies were carried out. AI Watch developed a conceptual framework for discussion with experts, and Member States have been engaged through a peer learning process. These first year activities are documented in the AI Watch report “Artificial Intelligence in

public services - Overview of the use and impact of AI in public services in the EU and proposed methodology to assess their impacts”.

Closely related to AI Watch, the JRC HUMAINT project aims is to provide a multidisciplinary understanding of the **impact of AI systems on human behaviour**. The project has three main goals: (1) To advance the scientific understanding of machine and human intelligence; (2) To study the impact of algorithms on human behaviour, especially on decision making and cognitive and socio-emotional development; (3) To provide insights to policy makers with respect to the previous issues. HUMAINT research is structured in four different scenarios with high social impact: 1) AI algorithms for decision making in criminal justice, 2) impact of AI on occupations within the labour market, 3) impact of Social robots on child development, and 4) impact of AI on music, creativity and culture. The HUMAINT project also organizes a yearly winter school on AI and its ethical, legal, social, economic and cultural impact. HUMAINT research results are regularly published in scientific journals.

Impact of AI on society is analysed in several research projects closely linked to AI Watch.

The JRC study on “Academic offer and demand for advanced profiles in the EU” aims at supporting the policy initiatives to ensure availability in the EU Member States of adequate advanced **digital skills** in a number of IT domains including Artificial Intelligence, High Performance Computing and Cybersecurity.

Data governance has become a key policy theme in Europe, but a shared vocabulary and established analytical frameworks are lacking. To increase understanding of this emerging field, The JRC Digitranscope project has systematized different approaches to data governance currently implemented or imagined across Europe, and has identified eight data governance models organised in four types: corporate governance, peer-governance, public-driven governance and co-governance.

Finally, another JRC activity linked to AI Watch was to participate in the **JRC Collaboration with Leading Science Centres & Museums**. The objective of the project is organise activities on AI, including Virtual/Augmented Reality experiences and workshops, notably at the *MuST* science museum in Milan and *Universiences* in Paris.

AI Watch results and analyses are regularly published on the AI Watch public web portal (https://ec.europa.eu/knowledge4policy/ai-watch_en). Most of the publications resulting from 2019 AI Watch activities were published in the first months of 2020. A list of published AI Watch reports is available in Annex.

Future outlook

In its first year, AI Watch has already contributed significantly to its main objective *to monitor the development, uptake and impact of Artificial Intelligence for Europe*. It has developed and proposed methodologies for data collection and analysis in a wide scope of AI-impacted domains, and has presented new results that can already support policy making on AI in the EU. In the coming months AI Watch will continue collecting and analysing new information, it will provide updated results and will further improve its methodologies, where possible. AI Watch welcomes your feedback. This report will be updated annually.

1 Introduction – Why a European Artificial Intelligence observatory?

The European Commission and the European Union (EU) Member States published in December 2018 a “Coordinated Plan on Artificial Intelligence” (COM(2018)795) on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation, and AI Watch, *the European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence for Europe*, was therefore launched in December 2018.¹

More recently, on 19 February 2020, the Commission unveiled its vision for a digital transformation that works for everyone. This includes a White Paper proposing a framework for Artificial Intelligence based on excellence and trust.² One particular challenge identified by the Commission is the extremely fast development of AI. Policymakers are struggling to monitor the AI landscape and analyse its uptake and impact to know where and how their intervention could tip the balance towards desirable outcomes for society, hence the essential role that AI Watch can play to support policy making on AI in the EU.

From AI Watch in-depth analyses, we will be able to understand better European Union’s areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education, and society.

All AI Watch results and analyses are regularly published on the AI Watch public web portal:

https://ec.europa.eu/knowledge4policy/ai-watch_en

The present document provides an overview on development of AI Watch in 2019. It first describes how we organised ourselves, and then presents the different activities of AI Watch and of some other JRC activities on AI that are closely related to AI Watch (e.g., HUMAINT, Digital Skills, Digitranscope). These activities aim to improve our understanding of AI itself, of the evolution of AI technologies, of the worldwide landscape of AI, of AI policy developments in the EU Member States, and of impact of AI on the economy, government, society, and on human behaviour.

¹ https://ec.europa.eu/knowledge4policy/ai-watch_en

² https://ec.europa.eu/info/sites/info/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf

2 What has been done until now to build the AI Watch observatory

Work on AI Watch started in December 2018. AI Watch is developed by the Joint Research Centre (JRC) of the European Commission in collaboration with the Directorate General for Communications Networks, Content and Technology (DG CONNECT).

We structured AI Watch in a number of different tasks or activities:

- Develop an overview and analysis of the “landscape” of AI in Europe, and globally: from research, to market, and society
- Monitor the evolution of AI technology
- Monitor the uptake of AI applications in selected sectors of the economy
- Assess the evolution of European market shares in robotics
- Gather information and provide overview of EU Member States' national initiatives on AI
- Provide an analysis on the use and impact of AI in public services

Browse AI Watch by topic

AI for the public sector
AI-enabled solutions can deliver shorter and richer feedback loops for all levels of governance, providing an opportunity to speed up, improve the efficiency and effectiveness of service delivery.

Data: a cornerstone for AI – Toward a Common European Data Space
For an application of AI to be ready for market entry it has to learn on the basis of training data. Additionally, it may need further data sources in order...

AI Landscape and Indicators
Front end methodologies have been applied to analyse the AI ecosystem and track its evolution.

Education and Skills
Education and training are crucial to harness AI, but AI can also help us rethink what competences and skills will be needed in the future to live...

Evolution of AI uptake
AI as a general-purpose technology can rapidly spread across industry sectors and yield strong positive growth effects.

Key Enablers
The Digital Single Market and its regulatory framework will provide key enablers to enhance AI adoption.

Social perspective
It is crucial to think how the concepts of autonomy and identity of individuals as well as security, safety and privacy issues might change under the influence of AI. AI WATCH...

Strategic Actions and Coordination
The EC coordinated action plan and Member States national strategies.

Browse AI Watch by country

- Develop an AI index, or dashboard, including the dimensions relevant for policy making
- Make information available to the different stakeholders on the AI Watch on-line portal.
- Monitor standardisation activities on AI (this activity started in 2020).

In addition, AI Watch will also provide analyses of:

- Education and Skills for AI
- AI key technological enablers (e.g. IoT, 5G, etc.)
- Data ecosystems
- Social perspective on AI.

In 2019 we developed methodologies under each of the above tasks and started producing initial results. From end 2019, AI Watch started publishing several reports on these methodologies and initial results. Reports and on-line results and reports are all available from the AI Watch portal³

The different sections of this report presents these initial results and reports.

2.1 AI Watch Steering Group

An AI Watch Steering group composed of Member States representatives was created in 2019. The Steering Group met twice in 2019. The steering group provides guidance to the Commission in the development of AI Watch. The group also serves to create links with Member States and to collect and validate information, for example on national AI strategies.

2.2 AI Watch team

AI Watch is developed by the Joint Research Centre (JRC) of the European Commission in close collaboration with the Directorate-General for Communications Networks, Content and Technology (DG CONNECT). Within JRC, AI Watch is under the responsibility of the Digital Economy Unit, part of Growth and Innovation Directorate. A list of JRC AI Watch task leaders is available in Annex.

³³ https://ec.europa.eu/knowledge4policy/ai-watch_en

2.3 Preliminary Dialogue with External Organisations

AI Watch established in 2019 preliminary dialogues in view of possible collaboration with several organisations, notably the OECD, the German Observatory on AI, the AI Observatory of the Politecnico di Milano, the AI Laboratory of the Jozef Stefan Institute in Ljubljana, and several industry associations.

2.3.1 OECD

AI Watch and the OECD initiated in 2019 a collaboration on the collection and presentation of national strategies and initiatives on AI in EU Members States. This information was published on both the AI Watch portal and on the OECD AI Policy Observatory in February 2020 (<https://www.oecd.ai/>). This collaboration will be further developed in 2020 and is envisaged to cover additional aspects such as AI metrics.

2.3.2 The German Observatory for AI

The German Observatory for AI, established by the Federal Ministry for Labour and Social Affairs. The Observatory was officially launched on 03 March 2020, but we have already had before the launch a productive dialogue to find possible synergies with several activities in AI Watch.

<https://www.denkfabrik-bmas.de/themen/kuenstliche-intelligenz>

2.3.3 The AI Observatory of the Politecnico di Milano

The AI Observatory of the Politecnico di Milano (Italy) is led by the Politecnico Management School and has already carried out two national surveys of AI uptake in Italy. The Observatory is one of many developed by the Politecnico in relation to digital innovation.

https://www.osservatori.net/it_it/osservatori/osservatori

Other relevant observatories of the Politecnico di Milano are for example the one on digital health, fintech, smart agrifood.

2.3.4 AI Laboratory of the Jozef Stefan Institute in Slovenia

The AI Laboratory of the Jozef Stefan Institute in Slovenia is involved in a number of AI-related projects as well as the OECD Observatory for AI policies (<https://ailab.ijs.si/>).

2.3.5 Industry associations

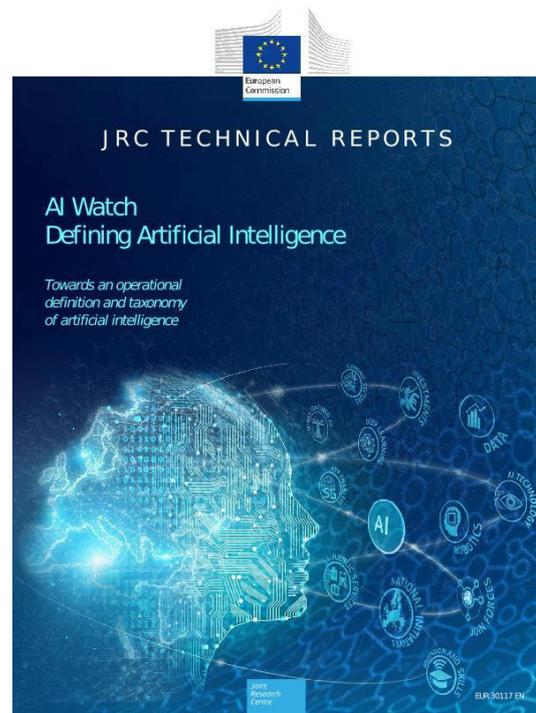
AI Watch has also been developing partnerships with several industry associations (see below the section on Understanding Impact of AI on the Economy).

3 Understanding Artificial Intelligence

A mandatory first step before starting analysing AI and its impact is to understand what AI is. AI Watch therefore developed in its first year an operational definition of AI published in the report “Defining Artificial Intelligence – Towards an operational definition and taxonomy of artificial intelligence”⁴. This report proposes an operational definition of artificial intelligence to be adopted for the monitory activities of AI Watch.

The AI Watch definition of AI was established by means of a flexible scientific methodology that allows regular revision. The operational definition consists of a concise taxonomy and a list of keywords that characterise the core domains of the AI research field. The AI taxonomy was designed to serve as a basis for analysing the global landscape of AI actors, and also for detecting AI applications in related technological domains, such as, robotics, neuroscience, internet of things, etc.

The definition of AI adopted by the EU High Level Expert Group on artificial intelligence served as a starting point. To derive the AI Watch operational definition, we then have, on the one hand applied natural language processing methods to scan and analyse a large set of AI literature and, on the other hand carried out a qualitative analysis of 55 key documents including artificial intelligence definitions from three complementary perspectives: policy, research and industry. We have collected definitions developed between 1955 and 2019, and summarised main features of artificial intelligence as reflected in the relevant literature.



We welcome feedback on this operational definition of AI, as we will review the definition in 2020

⁴ https://ec.europa.eu/knowledge4policy/ai-watch/defining-artificial-intelligence_en

4 Understanding the Evolution of Artificial Intelligence Technologies

4.1 AI History Timeline

To provide an easy-to-grasp overview of the history of artificial intelligence, AI Watch developed an AI history timeline visualization from an EU perspective. It includes selected important AI breakthroughs from the 1950's to today.⁵

Figure 1. AI History Timeline



1956: Dartmouth College AI Conference

The Dartmouth College summer AI conference was organized by John McCarthy, Marvin Minsky, Nathan Rochester of IBM and Claude Shannon. McCarthy coins the term artificial intelligence

Source: JRC.

The selection of the AI breakthroughs has been inspired by sources available online, and they have been classified according to the domains identified in the technical report AI WATCH. Defining Artificial Intelligence.

This AI history timeline is regularly updated. AI Watch welcomes contributions on breakthroughs particularly reflecting national initiatives and developments in the EU. A feedback form is available.

The dataset of the selected breakthroughs is published on the JRC Data Catalogue.⁶ It can be downloaded, and used. Suggestions for improving it are also very welcome.

4.2 Understanding current evolution and trends of AI technologies: the AI Watch “Alcollaboratory”

In 2019 AI Watch developed a methodology to assess current evolution and trends of AI technologies. The methodology is centred on building the *Alcollaboratory*,⁷ a data-driven framework to collect and explore data about AI results, progress and ultimately capabilities. From the collaboratory framework we later extract qualitative information related to the state of the art, challenges and trends of AI research and development.

⁵ https://ec.europa.eu/knowledge4policy/ai-watch/timeline-visualising-ai-history_en

⁶ <https://data.jrc.ec.europa.eu/dataset/76625e38-36a1-417f-b28f-b3380376643e>

⁷ <http://www.aicollaboratory.org/>

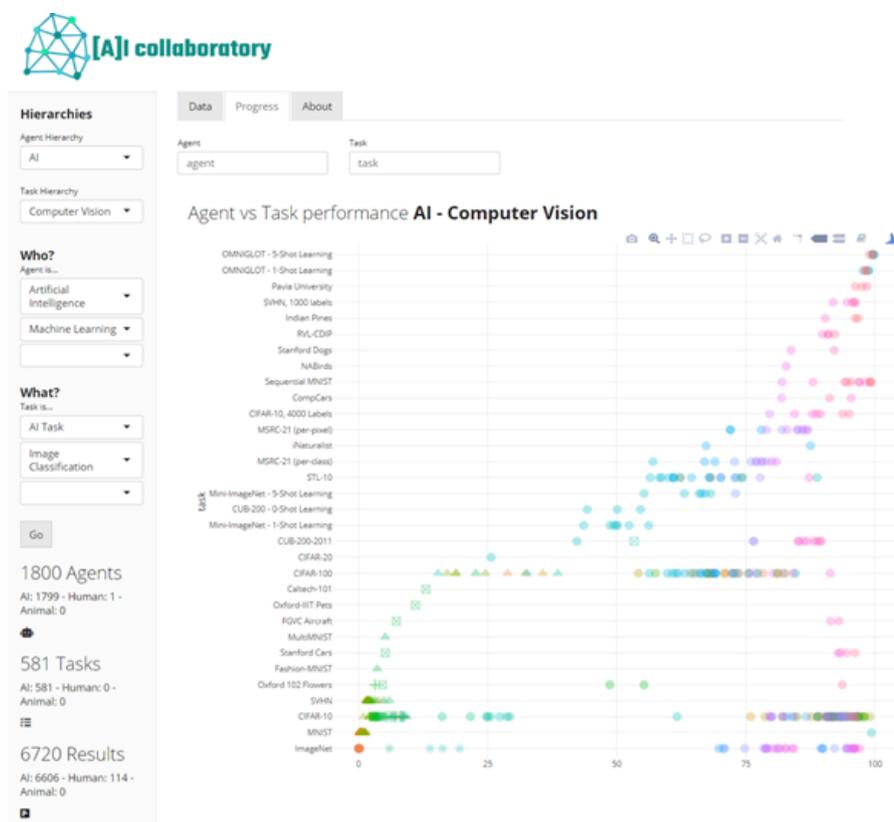
It is based on an understanding of the difficulties but possibilities of using an ability-based view rather than a task-based AI evaluation approach, and a thorough analysis of the requirements of the community.

Simply put, the *AIcollaboratory* (a) incorporates information about current, past and future intelligent systems; (b) integrates a series of behavioural tests, the dimensions they measure and for which kinds of systems; and (c) records the results (measurements) of a wide range of intelligent systems for several tests and benchmarks. The representations, aggregated information and data analysis come by using exploitation tools over the platform.

In a context of open science, the platform is populated in an open and collaborative fashion, facilitating cross-comparison and reproducibility. We follow a multidimensional perspective to model the information system behind the *AIcollaboratory*. The main idea is that each piece of information is characterised by a number of dimensions defining the “WHO” (e.g., AI systems) and the “WHAT” (e.g., tasks). There is a third major dimension: “HOW” (e.g., testing apparatus) for a specific result (fact) stored in the collaboratory.

Two screenshots of the *AIcollaboratory* are shown as examples and commented below.

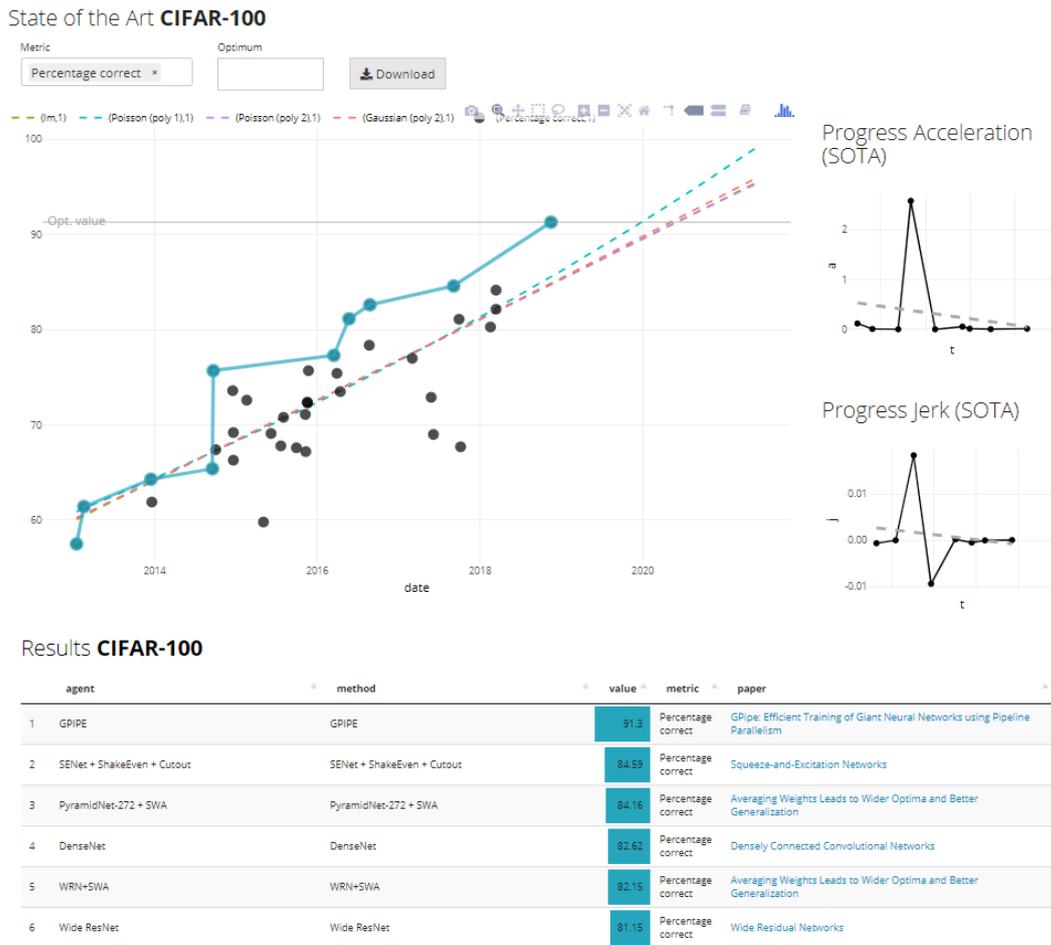
Figure 2. *AIcollaboratory* - AI systems vs task performance



Source: *AIcollaboratory*, JRC, 2020

AI systems vs task performance. On the left part of the screenshot, users can filter the different dimensions and hierarchies. The plot shows the results (using different metrics) obtained by different AI systems addressing different benchmarks (e.g., CIFAR, OMNIGLOT, MNIST, etc.) involving the selected task (i.e., image classification).

Figure 3. *Alcollaboratory* - Task progress



Source: *Alcollaboratory*, JRC, 2020

Task progress. Users can select any particular benchmark (for a specific task) to analyse progress over time with an overview of the best systems and the pareto frontier.

A prototype of the *Alcollaboratory* is available at www.aicollaboratory.org and more details are provided in the references below (Martínez-Plumed et al, 2020a, Martínez-Plumed et al., 2020b) and in the report “AI Watch: Methodology to Monitor the Evolution of AI Technologies “ presented below .

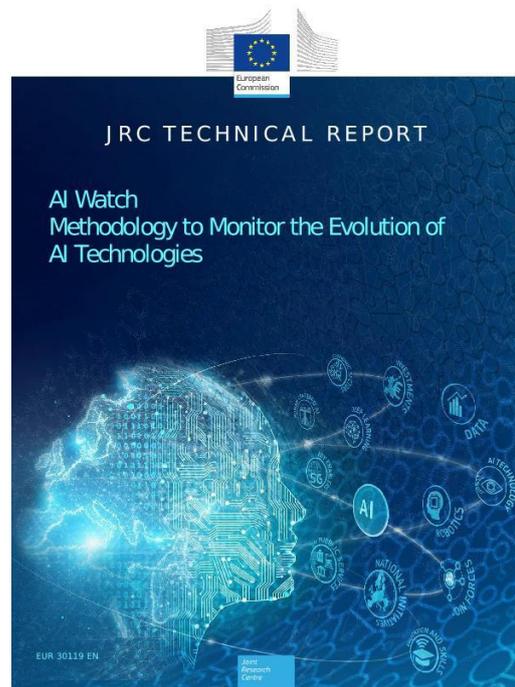
4.2.1 References for the *Alcollaboratory*

Fernando Martínez-Plumed, Jose Hernández-Orallo, Emilia Gómez, "Tracking AI: The Capability is (Not) Near", 24th European Conference on Artificial Intelligence (ECAI 2020), Santiago de Compostela, Spain, August 2020.

Fernando Martínez-Plumed, Jose Hernández-Orallo, Emilia Gómez, "Tracking the Impact and Evolution of AI: The *Alcollaboratory*", 24th European Conference on Artificial Intelligence (ECAI 2020), Workshop on "Evaluating progress of AI" (EPAI 2020), Santiago de Compostela, Spain, August 2020.

4.2.2 Report: “AI Watch: Methodology to Monitor the Evolution of AI Technologies”

In this report,⁸ we present the *AIcollaboratory* methodology to assess the evolution of AI technologies in the context of the AI WATCH initiative.



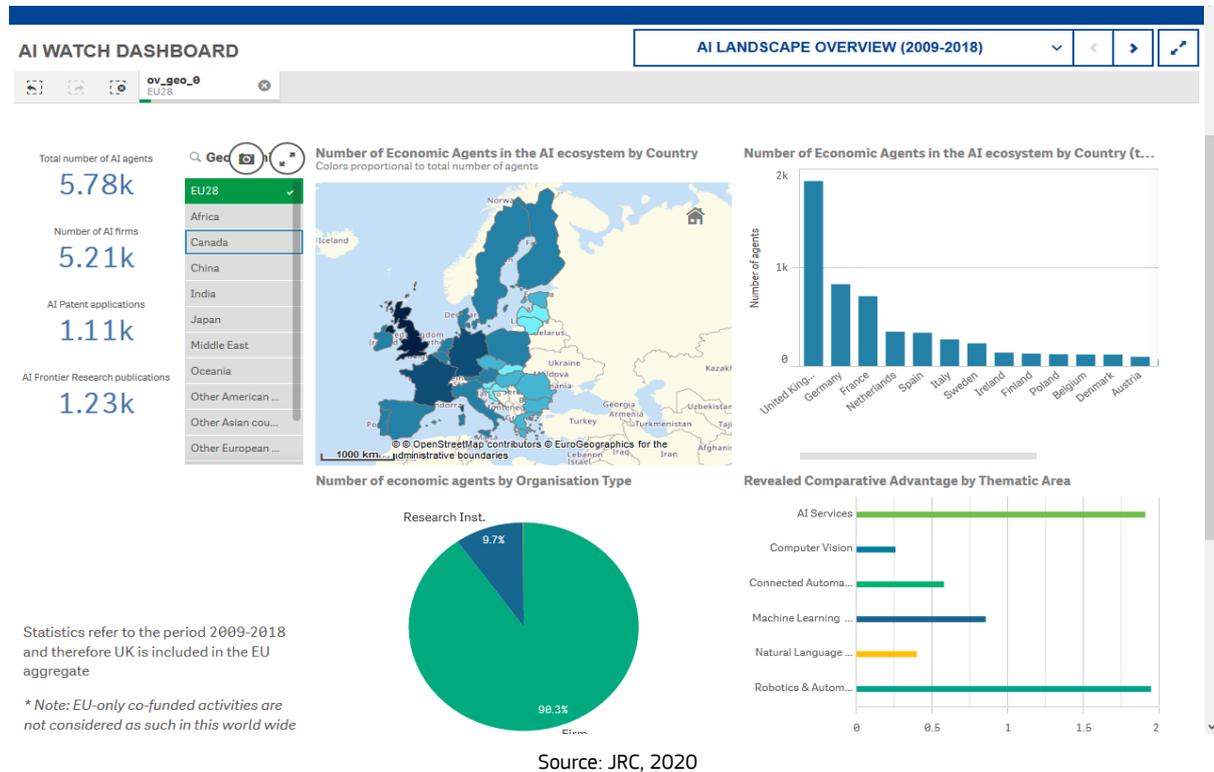
⁸ <https://ec.europa.eu/jrc/en/publication/ai-watch-methodology-monitor-evolution-ai-technologies>

5 Understanding the Worldwide Landscape of AI

5.1 On-line AI Landscape Dashboard

AI Watch developed in 2019 an overview and analysis of the worldwide AI landscape.⁹

Figure 4. AI Watch AI Landscape Dashboard



To this end, AI Watch used a methodology to assess AI as an emerging techno-economic segment (TES), capturing the entire emerging landscape:

- who are the key players,
- in which technologies they specialise,
- how they are distributed geographically,
- how they are connected to each other,
- how innovation spreads through the network,
- which technologies are consolidating.

The online AI Watch AI Landscape dashboard offers four perspectives on the data, presented by countries and by global regions (e.g. EU):

- AI landscape overview
- Areas of specialisation
- Industry
- R&D.

The dashboard includes data covering from 2009 to 2018 (therefore also including UK as EU Member State at the time).

⁹ https://ec.europa.eu/knowledge4policy/ai-watch/topic/ai-landscape-indicators_en

5.2 Report: “TES analysis of AI Worldwide Ecosystem in 2009-2018”

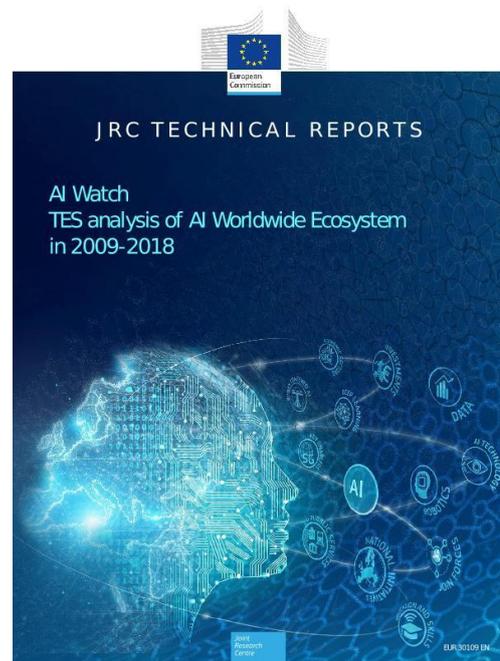
AI Watch also published the AI worldwide analysis in a report: “TES analysis of AI Worldwide Ecosystem in 2009-2018”¹⁰ comparing countries and regions in the evolving international industrial and research AI landscape of Artificial Intelligence.

The analysis presented is based on a unique database covering the years 2009-2018. The database has been specifically built from a multitude of sources to provide scientific evidence and monitor the AI landscape worldwide. Companies, universities, research institutes and governmental authorities with an active role in AI are identified and analysed in an aggregated fashion.

The report presents a wide variety of indicators on issues such as:

- the size of the AI ecosystem globally and at country level
- which are the main global competitors of the EU
- what is the level of industrial involvement per country
- what are the firms’ demographics, profiling economic agents according to their strengths in innovation and take-up of AI, including their patenting performance
- what is the degree of internal and external collaborations between EU and non-EU firms and research institutions.

The analysis of the AI activities developed by agents in the covered territories provides insights on their areas of specialisation, highlighting the relative strengths of the EU and its Member States in the global landscape. Each section of the reports offers a focus on EU Member States.



We welcome feedback on the AI landscape report and dashboard, which will be periodically updated.

¹⁰ https://ec.europa.eu/knowledge4policy/ai-watch/ai-landscape-2009-2018_en

6 Measuring Development and Impact of AI

AI Watch aims to develop a dashboard of **AI indicators and metrics relevant for policymaking**. This dashboard will include indicators covering the different activities of AI Watch described in the present report, with the objective to build an “AI Index” from the outputs of AI Watch. Relevant indicators from external sources may be included as well. AI Watch will explore feasibility of integration of the identified indicators into one or several composite indicators.

This activity is developed in collaboration with the AI Index published by Stanford University¹¹ and with OECD.

A methodology report “Towards an AI Watch Index - Approach to indicators identification and AI Index construction” describing the steps planned to identify a set of indicators suitable to provide a comprehensive and balanced overview of the various topics addressed by AI Watch is being finalised and will be published soon. It describes an approach to indicators identification and analysis in order to identify, select, and collect a number of indicators, classifying them in order to allow for comparison among countries and regions in the evolving international economic, social, industrial and research landscape of AI. The report also offers a first list of indicators, described along with a proposed classification template, as an example for the further identification activity in different topics.

¹¹ <https://hai.stanford.edu/research/ai-index-2019>

7 Understanding AI Policy Developments in the EU Member States

7.1 National strategies on Artificial Intelligence

In December 2018, the European Commission presented a [Coordinated Plan on Artificial Intelligence](#). The Coordinated Plan aims at ensuring complementarity and synergies between national and EU level actions to maximise the impact and spread the benefits of AI across Europe. It also provides a strategic framework for national AI strategies. One of the key priorities of the Coordinated Plan is to encourage Member States to develop their national AI strategies by the end of 2019 outlining investments levels and implementation measures.

AI Watch published in February 2020 its first annual report on: “National strategies on Artificial Intelligence: A European perspective in 2019”.¹² This report is based on information published and validated by the Member States and complemented with information from the EC-OECD STIP Compass database.¹³

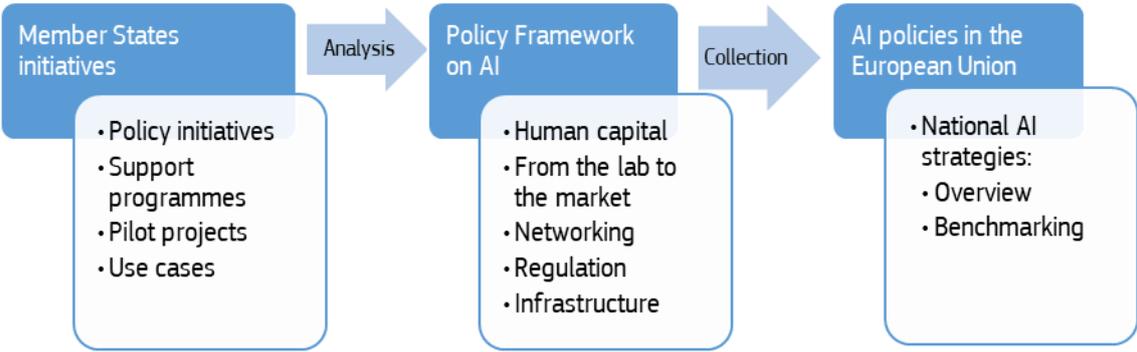
This activity is developed in collaboration with the OECD AI policy Observatory (OECD.AI).

The AI Watch report information is also available as a set of country pages on the AI Watch Portal,¹⁴ with cross-links to [OECD.AI](#).

The objective of the AI Watch report is to present and **gather information on all EU Member States' national AI strategies** in a structured and comprehensive way. It aims to help Member States to compare their strategy and to identify areas for strengthening synergies and collaboration. Published national AI strategies are analysed to identify the most relevant policy areas and to develop a common **AI Policy Framework** that can be used for the presentation of policy initiatives. Figure 5 presents the methodology to collect national AI strategies and initiatives from EU Member States.



Figure 5. Methodology to collect EU Member States National AI Strategies and initiatives



Source: JRC

The policy initiatives identified in the AI national strategies relate to the following policy areas:

¹² <https://ec.europa.eu/jrc/en/publication/ai-watch-national-strategies-artificial-intelligence-european-perspective-2019>
¹³ <https://stip.oecd.org/About.html>
¹⁴ https://ec.europa.eu/knowledge4policy/ai-watch/national-strategies-artificial-intelligence_en

- human capital
- from the lab to the market
- networking
- regulation
- infrastructure.

Initiatives categorised as **human capital** target all policies to foster the educational development of people in using and developing artificial intelligence solutions. It includes aspects of formal education and training (e.g. reforms of educational systems towards inclusion of AI courses and programs), vocational and continuing learning (e.g. training of existing workforce to obtain AI-related skills and competences), and labour market intelligence and needs (e.g. identifying forthcoming skill needs due to changes in technology developments). **From the lab to the market** encompasses policy initiatives to encourage research and innovation in AI towards business growth in the private sector and increased efficiency of public services. This section also includes policy instruments to facilitate testing and experimenting newly developed AI pilots and services. **Networking** presents all policy initiatives related to AI collaborations across private and/or public sectors and directed to increasing the (inter)national attractiveness of the country (e.g. policies aiming at attracting foreign AI talented individuals and firms to the focal country). This category also includes policies related to the dissemination and uptake of AI such as promotion campaigns and mapping of AI players and applications. **Regulation** highlights policies for the development of ethical guidelines, legislative reforms and (international) standardisation. Finally, **infrastructure** covers initiatives to encourage data collection and responsible usage of it, and to foster the digital and telecommunication infrastructure.

Country pages published on the AI Watch portal are regularly updated. The report itself will be updated by end 2020 and in subsequent years. While this first report aimed to assemble a synthetic overview of AI policies developments in Europe in terms of, it is envisaged that subsequent reports will provide more in-depth analyses based on benchmarking indicators.

7.2 Estimating AI investments in the EU Member States

In spite of a large interest in AI, among many open questions around this promising technology, the question of what is the actual level of investments in AI is particularly difficult to answer. Various sources provide various figures. This diversity blurs the understanding of the AI-driven revolution among policy makers and business leaders and limits informed decision-making. AI Watch developed in 2019 an original and comprehensive methodology to estimate AI investments and applied it to assess AI investments in Europe in 2018.

AI Watch published the report “Estimating investments in General Purpose Technologies: The case of AI Investments in Europe”¹⁵

We welcome feedback on this report, which will be annually updated.

The AI Watch framework for estimating AI investments in an economy rests on three assumptions:

- First, it **considers AI as a general-purpose technology (GPT)**. Being a GPT, the economic and innovative potential of AI lies in its capacity to modernise the economy rather than in the strength of the AI producing sector. Consequently, similar to other digital GPTs, to trigger the wave of AI-driven



¹⁵https://ec.europa.eu/knowledge4policy/ai-watch/estimating-investments-general-purpose-technologies-case-ai-investments-europe_en

wave of innovation, comprehensive support and funding of AI development and translation of the opportunities offered by AI into new business models and processes is needed.

- Second, building on the fact that AI is a GPT, the current framework considers among AI investments not only investments in the core technology, but in complementary assets and capabilities such as skills, data, product design and organisational capital. Considering the relevance of the wider focus for an economy-wide uptake of AI, the current framework groups AI-related investments into three target categories: “Talent, skills and life-long learning”, “From the lab to the market” and “Data, technology and infrastructure”.
- Finally, the framework recognises **different roles that the public and private sectors play** in the process of AI creation and implementation and provides investment figures of both sectors. Overall, by highlighting the role of different stages, actors and capabilities involved in the AI uptake, the current report attempts to enlarge the perspective on the efforts necessary to roll out AI in an economy.

According to the JRC estimates, in 2018, the AI investments in Europe are estimated to be in the range of **7.0 to 8.4 Billion Euro**. This corresponds to 35 to 42% of the annual investment target set in the Coordinated Action Plan. 2018 spending in the EU28 is equivalent to 16.3 Euro per capita or 0.04 percent of the EU GDP. For comparison, in 2018, total R&D spending in the EU accounts for 2.11 percent of the EU GDP.

Table 1. AI investment highlights in 2018 for the EU28.

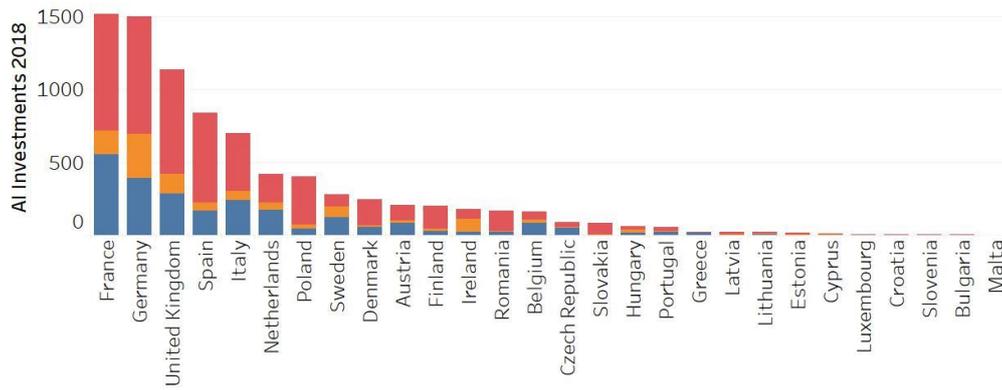
EU28	total [BEUR]	% of GDP	per capita [EUR]	% of target
min scenario	7.0	0.044%	13.8	35.2%
max scenario	8.4	0.053%	16.3	41.8%

Source: JRC based on EUROSTAT, Spintan and Intan-Invest data.

The AI Watch framework developed in 2019 groups AI-related investments into three target categories. The majority of investments is targeted at labour and human capital covered by “**Talent skills and life-long learning**” target (58%). In this group of expenditures, AI ICT specialists’ compensation represents the largest item. Expenditures on AI-related “**Data, technology and infrastructure**” account for nearly 30% of the total AI investments in the EU with most of investments going into “Computer software and databases”. The smallest stream of funding is directed at the “**From the lab to the market**” target, which includes expenditures on R&D and such intangible capital assets as brand, product design and organisational capital.

Regarding the **AI investments at the Member States level**, the highest absolute amounts are spent in the largest countries. France, Germany and the United Kingdom score top three with nearly 50% of the total AI expenditures in the EU. This picture changes substantially when the per capita investments are considered. **Nordic countries and Ireland** are the top scorers, disbursing more than 35 Euro per capita on AI investments. In general, there is a huge variation among the Member States in per capita expenditures, with developing economies spending considerably less than developed ones. Moreover, considerable differences in all expenditure categories exist across the European countries. This reflects structural diversity of their economies and **different levels of AI readiness** of the EU Member States.

Figure 6. AI investments in the EU Member States



Target

- Talent, skills and life-long learning
- From the lab to the market
- Data, technology and infrastructure

Source: JRC based on EUROSTAT, Spintan and Intan-Invest data.

8 Understanding Impact of AI on the Economy

8.1 Take up in selected sectors of the economy, in selected regions

AI as a general-purpose technology can rapidly spread across industry sectors and yield strong positive growth effects. The key AI Watch activity in 2019 on understanding impact of AI on the Economy was the preparation of a methodology to monitor the uptake and impacts of AI applications across the economy, including geographical and sector comparison. The methodology is designed to:

- Assess current state of AI adoption in different sectors to act as benchmark for future comparison,
- Identify within-sector variations across geographies and areas of application,
- Deliver comparative results across sectors, and agreed indicators for EU-wide assessment,
- Identify cross-sectorial issues, and specificities of each sector,
- Identify a number of representative case-studies to analyse in further detail at regular intervals and act as “probes” of change over time.

The methodology proposed seeks to achieve both the dynamic breadth of coverage needed to understand the rapid evolution of the technology and how it is perceived in the scientific and public spheres, and the in-depth understating of impacts at organisational and geographical level in selected sectors. It is not the purpose of the methodology to achieve comprehensiveness across all sectors, nor statistical robustness, but rather to deliver both quantitative and qualitative measures that can be replicated over time in selected sectors following a step-wise approach. The four main elements of the methodology described in this report include: Scanning and analytics, Partnerships, Reviews and Longitudinal panel studies.

The methodology is described in the AI Watch report “Methodology to Monitor the Uptake and Impact of AI Applications”¹⁶

The preparatory activities contributing to the report are outlined below.

8.2 Participation in meetings

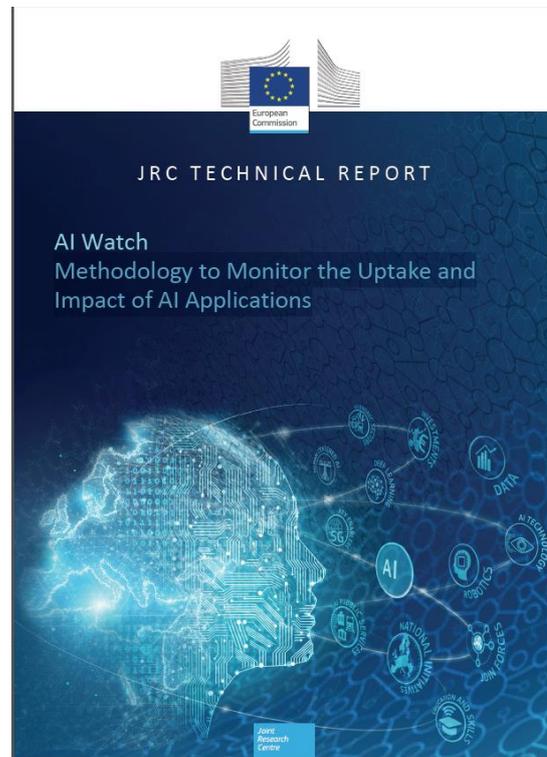
Under this activity, AI Watch participated in 2019 in a number of meetings.

8.2.1 Science Meets the European Parliament on AI, 5-7 February 2019

The panel discussion on AI with the participation of two Members of the European Parliament, and the Chair of the AI study group of the Economic and Social Committee during the Science Week at the European Parliament organised by the JRC was an opportunity to understand the perspectives on AI of the different political groupings in the European Parliament.

8.2.2 Geospatial World Forum, Amsterdam 1-4 April 2019.

The Geospatial World Forum is an annual event taking place in different parts of the world and bringing together many CEOs and senior partners of geospatial companies, as well as senior government decision makers from around the world. Its global reach with many participants from Asia and Africa, in addition to those from the Americas and Europe is a hallmark of the event. The event demonstrated that the geospatial



¹⁶ https://ec.europa.eu/knowledge4policy/publication/methodology-monitor-uptake-impact-ai-applications_en

sector is very diffused and dynamic. It spreads now from the architecture, engineering, and constructions sector to space, logistics, transport, and environmental management. There are many start-ups and particularly in the space sector but not only, with all major venture capital funds having now dedicated chapters on the space and geospatial sector. This is changing dramatically a sector that was traditionally dominated by the public sector as both data provider and customer. Technological developments, such as miniaturisation of satellites, cloud computing, AI, and Machine Learning enable greater participation of the private sector and individuals fostering innovation and creating new business opportunities. As a follow-up of the workshop JRC commissioned a study of AI in the geospatial sector to be completed by March 2020.

8.2.3 High level conference on AI in aviation, 23 May 2019

The conference organized by Eurocontrol in Brussels on AI in aviation had the objective of providing a state of the art overview of the latest developments in the field of artificial intelligence and its application to business developments both inside and outside aviation. The conference was attended by over 300 participants largely from the aviation industry, but also included a strong delegation from DG MOVE and CNECT. The key message of the conference is that AI is clearly becoming more and more important for the entire aviation sector, which has traditionally been open to technological innovation, but the challenges are many like in other sectors. Improving the management of data within the organisation, as well as starting to share such data with other stakeholders in the ecosystem are clear key challenges. A particularly European challenge is also to develop mechanisms and European computing infrastructures to share the data safely and in respect of the European legal framework.

8.2.4 Futures workshop on AI in legal and professional services, London 14 July 2019

The UK launched its [Industrial Strategy](#) in 2018 around four main grand challenges: AI and data, ageing society, clean growth, and the future of mobility. This workshop was organised by the project “Innovating Next Generation Services through Collaborative Design”, which focuses on the impact of AI and related technologies on mid-sized law and accountancy firms. The project is one of three funded by the [UK industrial Strategy Challenge Fund](#) under the heading of [Next-Generation Services](#). The discussions indicated that both legal and accounting services will be profoundly shaken up by AI and big data analytics with different characteristics. Accounting is likely to see a further initial dominance of the big firms as they hold much of the data on which to build AI applications. In the medium run however the big Internet platforms are likely to erode their market share. For legal services, this challenge will come much sooner as the likes of Google and Amazon are already starting to leverage their data to provide alternative legal services. The participants explored plausible future scenarios to provide input for the subsequent stages of the project.

8.2.5 AI in critical industrial applications project workshop, 23 September 2019, Brussels

The study on AI in critical industrial applications commissioned by DG GROW and EASME, the European Agency for SMEs, to McKinsey International addressed the impacts of AI in critical industrial applications, including the Industrial Internet of Things, the automotive sector, and health. Its policy recommendations were [published](#) on the 5th November 2019 providing input to the SME Strategy published on 10th March 2020 [COM(2020)103final].

8.3 Partnerships with industry associations

AI Watch has been developing partnerships with the following major industry networks:

[Eurocommerce](#) which is the umbrella organisation representing some six million retail and wholesale trading companies. Their support and that of its members will be crucial to monitor the uptake and impact of AI in this key sector of the economy.

[DigitalEurope](#) is a leading trade association of digitally transforming businesses. It includes some 35,000 businesses in different sectors and takes active part in the policy dialogue in Europe.

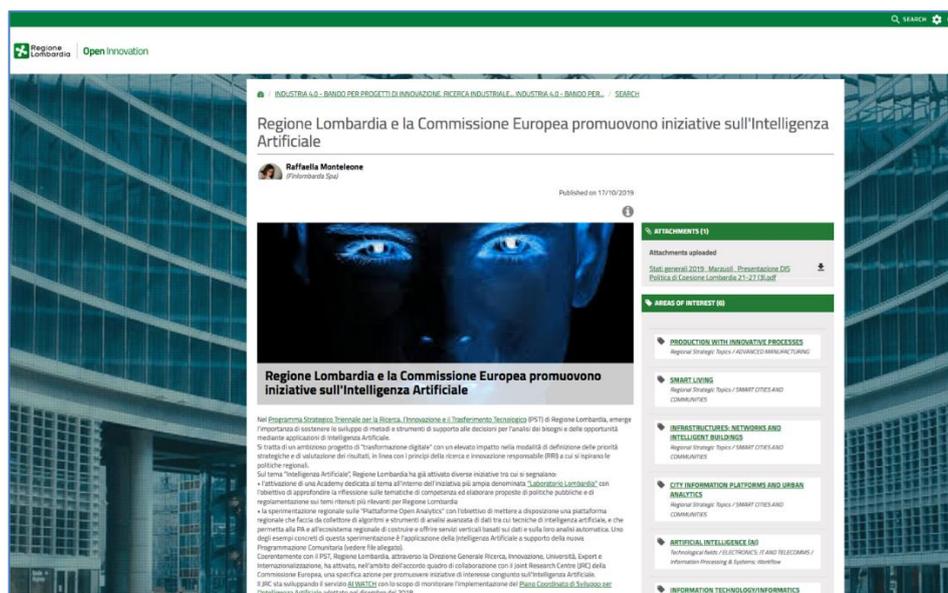
[The European Digital SME Alliance](#) is a network of small and medium-sized ICT enterprises in Europe, representing about 20,000 digital SMEs.

With these networks, and others that we will contact in the coming months, we are developing a partnership to organise the longitudinal panel studies discussed in the above-mentioned Methodology report.

8.4 Partnerships with Regional Authorities

AI Watch set in 2019 the first of several partnerships with the Regione Lombardia with which the JRC has established a specific Collaborative Agreement to support AI Watch. We have already had two meetings, one cross-sectoral and one specific to the health sector to explain the concept and recruit the panel members. We see this as a very powerful instrument to be able to understand better the impact of AI as seen from multiple perspectives in the context of the regional ecosystem: employers, researchers, public administrations, workers, and social actors in the region etc. This will provide a greater richness of regional understanding across the different parts of Europe as all too often aggregate numbers of effects hide very different realities at regional and local levels.

Figure 7. Announcement of collaboration Regione Lombardia and European Commission on AI Watch



Source: Regione Lombardia

8.5 Evolution of the European Market Shares in Robotics

AI develops computer programs to accomplish tasks normally performed by human intelligence. Robotics instead produces programmable machines (i.e. robots) to perform autonomous or semi-autonomous actions. The combination of AI and robotics gives birth to 'artificially intelligent robots' that carry important socio-economic implications. Therefore, robotics particularly emerges as a field in which Europe must keep its competitive advantage to the benefit of its economies and societies. AI Watch developed in 2019 various activities to respond to this need and to support policy makers with useful information on the EU strategic advantages in the field of robotics.

AI Watch carried out in 2019 the following activities:

- Participation in the Conference of European Robotics Forum organised in Bucharest (20-22 March, 2019). Discussions and exchanges about the type of data by International Federation of Robotics (IFR).
- Production of a report 'Tracking the EU robotics market shares: data and methodology' which presents an overview of literature and policy reports together with relevant data sources to provide some snapshots of the EU trends in robotics. Specifically, the report reviews academic literature and policy reports focusing on both industrial robots and service robots. Subsequently, it presents alternative ways to calculate the EU robotics shares from different data sources and it describes what type of shares these data sources can help providing. The data sources considered so far are:
 - International Federation of Robotics;
 - United Nations ComTrade;
 - Eurostat Aggregate Statistics;

- DealRoom data;
- Robot Report.

Finally, the report discusses the methodological challenges to track the European market shares in robotics. These challenges mostly relate merging heterogeneous data to estimate the EU shares for robotics demand and supply, and for industrial versus service robots.

The report is currently under finalisation and will be published shortly.

Future planned activities include:

- To develop more interaction with the EU Robotics Public-Private Partnership.
- To develop a methodology to calculate the EU market shares in robotics.
- Calculating and analysing the EU market shares in robotics during the past 10 years.

8.6 Monitoring Standardisation in AI

The main objective of this new AI Watch activity which started in 2020 is to monitor and gather information on the current work from the relevant international Standards Developing Organisations (SDOs) on the Artificial Intelligence framework.

A Class A liaison has been established with ISO/IEC JTC 1/SC 42 –Artificial Intelligence. Whenever possible, AI Watch will play an active role in the working groups, promoting European proposals to be considered in standards development.

AI Watch will also identify the other most relevant SDOs (e.g. IEEE, ITU-T, CEN-CENELEC, W3C), monitoring what is happening in AI standardisation activities carried out by them, and play an active role when necessary and feasible.

9 Understanding use and impact of AI in the public sector

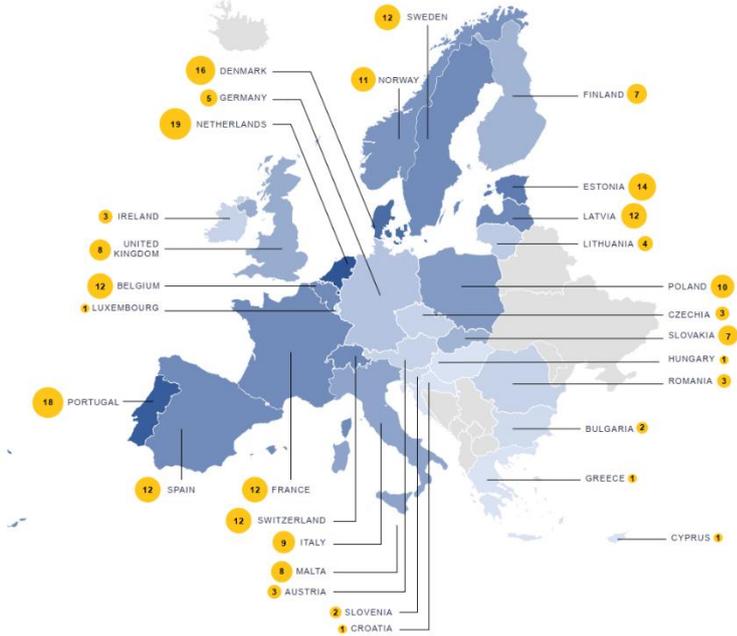
The potential benefits of AI for the activities of governments and the public sector are argued to be massive and AI is expected to bring solutions to various societal challenges. However, very little is known on how governmental organisations adopt and integrate AI within their operations. In this perspective, the focus for the first year AI Watch was to start exploring current use of AI in public services, analysing information on EU Member States activities, and to propose a methodology for assessing the social and economic impact of the use of AI in public services.

9.1 Overview of AI use in public services in the EU

AI Watch conducted in 2019 an analysis of the state of the art of the literature of AI in public services, including a literature and policy review, and the identification of main research gaps, theoretical approaches and practical use cases. This review showed in particular that there is currently a large gap between research on AI in the private and the public sectors, with the former gaining almost all the research attention. Furthermore, there seems to be an imbalance between the development potential and the effective adoption and use of AI solutions. The literature review also highlighted the wide variety of different AI technologies and applications for use in public services, each with different aims and effects.

AI Watch then conducted an exploratory analysis, identifying emerging strategies and practices across EU Member States so to learn from concrete experiences of deployment of AI in public services. This resulted in a collection of 230 AI use cases in EU Member States and an analysis of their main characteristics, technological dimensions, value drivers and potential impact. The analysis of the current sample shows the diversity of AI types and purposes, as well as the policy areas in which these are implemented, providing a rich – though preliminary – overview of the use of AI in public services in the EU.

Figure 8. AI Watch overview of AI initiatives



Source: JRC analysis

9.2 Outlining a methodology for assessing impacts of AI in public services

The exploratory analysis highlighted that a methodology to assess both positive and negative impacts of introducing AI is required. Therefore, AI Watch developed a first outline and proposal of conceptual framework underpinning the development of the methodology to assess the social and economic impact of AI in public services, for discussion with experts. This framework and methodology will be further developed and validated in the following steps of the research.

AI Watch also carried out a review of the Member States national strategies on AI, focusing on the activities dedicated to enhancing use of AI for the public sector and to improve public services delivery. From this analysis, emerged the wide variety of initiatives that Member States are putting in place or intend to put in place, with different depth and scope of initiatives. AI Watch also designed a survey for gathering insights directly from Member States. The survey also highlighted what Member States are expecting from AI Watch, so to lay the foundations for future research collaborations.

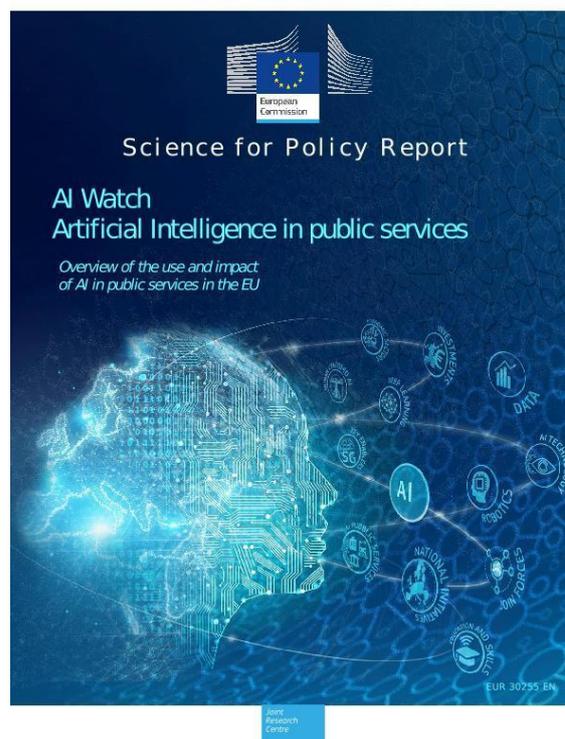
9.3 Peer learning with and among Member States on AI for the public sector

In the context of this exploration and analysis of use and impact of AI in public service, it was considered crucial to engage Member States at both policy and technical level. AI Watch thus decided to involve actively the “eGovernment Action Plan Steering Board” of Member States representatives, to provide guidance and support. This included a formal presentation at the 10th meeting of Steering Board on 21st June 2019 and discussions in other policy events, including for example the Tallinn Digital Summit on 16-17 September 2019, and the Policy Dialogue of the World Leadership Alliance – Club de Madrid on Digital Transformation and the future of Democracy, Madrid 21-22 October, 2019.

Furthermore, a Peer-Learning process with and among Member States has been formally initiated to facilitate exchange of lessons learned and possible faster adoption of AI-enabled systems and technological solutions in the public sector. In this respect, it has been also agreed to build synergies with activities conducted by JRC with the DIGIT Directorate General of the Commission, to ensure complementarities and increase the contribution of AI Watch to the EU Digital Strategy and the Digital Europe Programme.

9.4 Report “Artificial Intelligence in public services - Overview of the use and impact of AI in public services”

The AI Watch report “**Artificial Intelligence in public services - Overview of the use and impact of AI in public services**” published in July 2020 provides more information and details on the activities and analyses described above.¹⁷

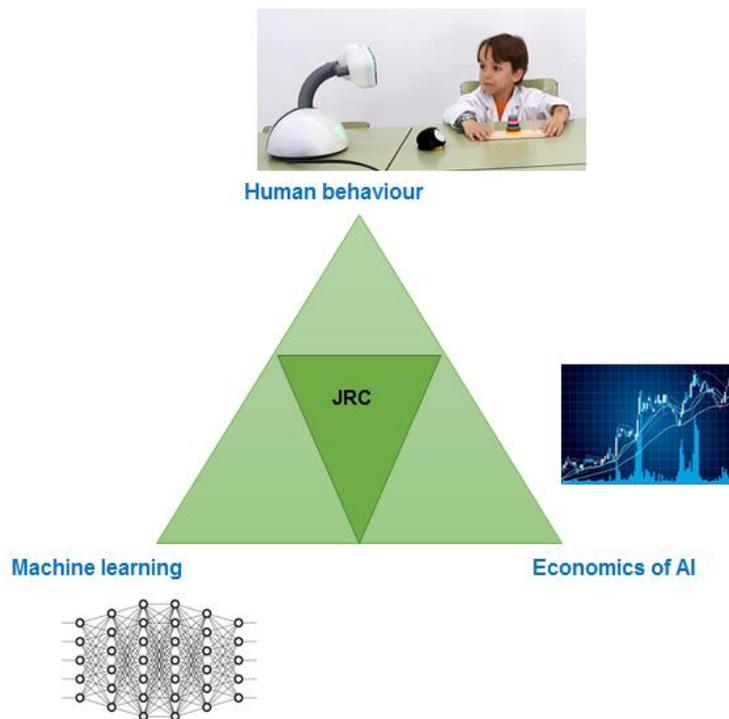


¹⁷ <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/ai-watch-artificial-intelligence-public-services>

10 Understanding Impact of AI on Human Behaviour (HUMAIINT)

This section provides a summary of HUMAIINT research activities. HUMAIINT is a project closely related to AI Watch. Its aim is to provide a multidisciplinary understanding of the impact that AI systems have on human behaviour. The project has three main goals: (1) To advance the scientific understanding of machine and human intelligence; (2) To study the impact of algorithms on human behaviour, especially on decision making and cognitive and socio-emotional development; (3) To provide insights to policy makers with respect to the previous issues.

Figure 9. HUMAIINT three goals



Source: JRC

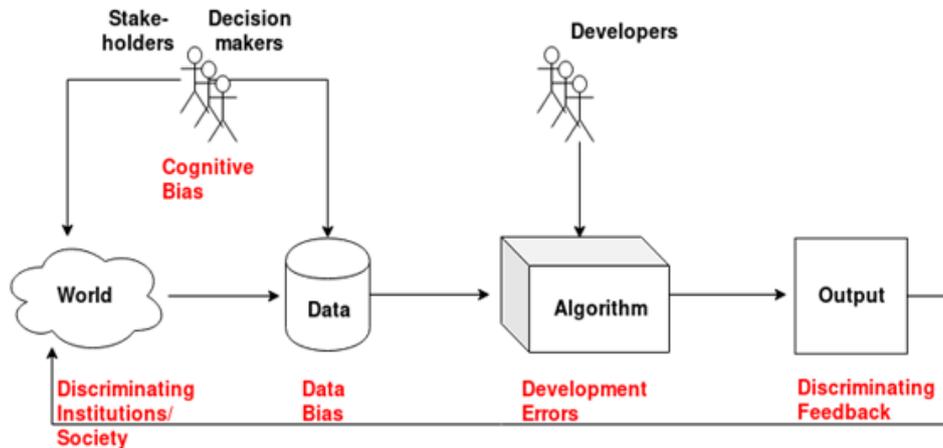
HUMAIINT research has three main characteristics: it is interdisciplinary, combining methodologies from machine learning, economics and cognitive science; it is reproducible, generating open publications, datasets, code and research protocols; and it is collaborative, as we work with researchers from different institutions worldwide. Through our research we also promote value-centered and ethical approaches for the development and application of AI systems and we are actively engaged in global initiatives on AI & Human Rights.

In order to have a broad understanding of the impact of AI on human behaviour, we research on four different scenarios with high social impact and then establish commonalities between them to extract scientific and policy-relevant conclusions. These scenarios are briefly presented below

10.1 Algorithms for decision making in criminal justice

In this first scenario we study algorithmic fairness in computer-assisted decision making. We focus on the causes of discrimination and the potential sources of biases that may occur in different parts of the decision making process. To that extent, the following figure illustrates a decision making process made by a data-driven algorithm and the potential sources of bias.

Figure 10. Decision making process made by a data-driven algorithm



Source: JRC

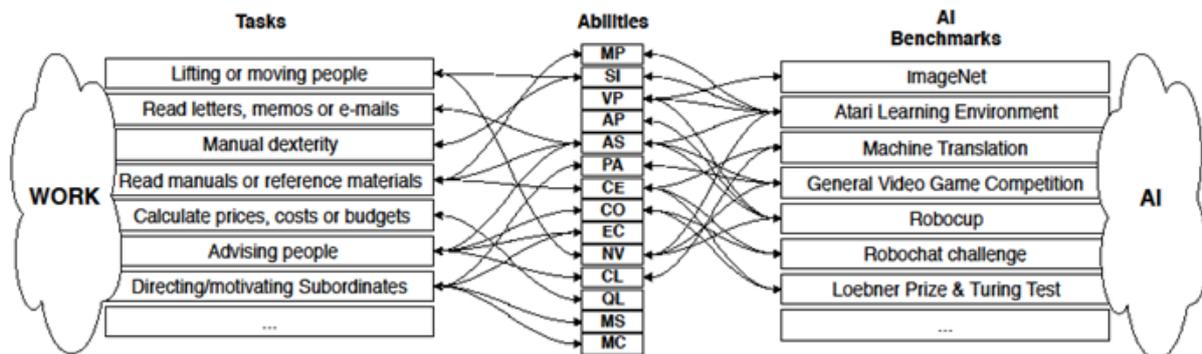
We evaluate human and algorithmic decisions by exploring the trade-off between predictive performance and group-fairness metrics. Towards identifying the sources of discrimination, we design evaluation experiments to isolate the influence of data and of different parts of a machine learning pipeline. In addition, we use machine learning interpretability to identify important features for black-box models.

Our main case study is assessing re-offense risk of defendants in Catalonia where human and machine evaluation are based on information from a structured professional judgement (Tolan et al., 2019). The framework used in our experiments is open source and can be applied in similar contexts where data is available (<https://gitlab.com/HUMAINTE>).

10.2 The occupational impact of AI

In this scenario we develop a framework for the analysis of the impact of AI on occupations within the labour market as proposed in (Tolan et al., 2018). We link occupations, defined in terms of tasks, to AI progress through an intermediate layer of cognitive abilities as illustrated in the figure below. These cognitive abilities are the ones required to perform tasks, as illustrated in the following figure.

Figure 11. Tasks and AI progress linked through cognitive abilities



Source: JRC

We use the AI Watch *AI collaboratory* (<http://www.AICollaboratory.org/>) repository on AI benchmarking initiatives to identify variations in research activity in different AI topics to approximate future expected progress. On the work-related side we identify variations in task performance across occupations by combining three international data sources that contain information on tasks: PIAAC (Programme for the International Assessment of Adult Competencies), EWCS (Eurofound's European Working Conditions Survey) and O*NET (Occupational Information Network). Finally, we link these information by mapping both sides to cognitive abilities.

This framework gives insights into AI's impact on occupations that goes beyond mere workplace automation by further identifying the abilities which are most likely going to be performed by AI. Moreover, it enables the simulation of multiple scenarios in which advancements in different AI areas can have different transformative effects on occupations.

10.3 Social robots and child development

There is a large amount of studies exploiting the use of social robots (embodied AI) as tutors or peer learners in educational contexts. In this scenario we aim to advance the scientific understanding of the impact that social robots have on children cognitive and socio-emotional development, with a focus on informal settings. Towards this direction we use various existing robotic platforms to conduct real-life user studies with children and design specific robot behaviours and interaction scenarios (Charisi et al., 2019). We observe the need to consider aspects such as cultural context in the design of child-robot interaction settings (Charisi, 2019a) and we address the ethical challenges related to the use of social robots with children as vulnerable population (AI and child rights policy, workshop report, UNICEF, New York, 2019, <https://ai4children.splashthat.com/>).

10.4 The impact of AI on music, creativity and culture

Finally, in this scenario we study how the use of AI a creative context, music, can influence human artistic practice, taste and culture. The application of AI to music has already been studied in the literature for many decades, and presents numerous unique opportunities for a variety of uses, such as the recommendation of recorded music from massive commercial archives or the (semi-)automated creation of music. In these contexts, AI can produce outcomes in a domain fully entrenched in human creativity. In (Sturm et al., 2019) we address two perspectives of AI applied to music creation: copyright law and engineering practice, and collects a set of questions which need to be answered such as how authorship and copyright is reconsidered in AI-generated music or how to ensure fairness and transparency in the use of AI in music. In (Porcaro and Gomez 2019), we present a methodology to assess the impact of music recommendation diversity, or the lack thereof, on music listening experiences. In our work we intend to better understand how AI is changing and can change our opinion about music and our relationship with music for better and for worse.

10.5 Transversal HUMAINT activities

The HUMAINT project organizes a [yearly winter school on AI and its ethical, legal, social, economic and cultural impact](#).

HUMAINT also contributes to related research initiatives such as the following ones:

- Diversity in AI (<https://divinai.org/>) is a project where we contribute to research and develop a set of diversity indicators, related to AI developments, with special focus on gender, geographical location and academia vs industry representations.
- International Consortium for Socially Intelligent Robotics (<https://mypersonalrobots.org/>)
- TROMPA (<https://trompamusic.eu/>), an H2020 project what researchers on how to combine human and machine intelligence for the enrichment of public-domain music archives.
- Paradigms of Artificial General Intelligence and Their Associated Risks (<https://www.cser.ac.uk/research/paradigms-AGI/>), project at Centre for the Study of Existential Risks, University of Cambridge.
- Participation at Expert Meeting on Predictive Policing, [Police and Human Right Programme \(PHRP\) of Amnesty International Netherlands](#).
- Participation in global initiatives on AI & Child rights working groups (ITU, UNICEF) <https://ai4children.splashthat.com/>

10.6 Key HUMAINT publications

Charisi, V., et al. (2019). *Expressivity for Sustained Human-Robot Interaction*. Workshop in ACM/IEEE HRI2019, March 11-14, Daegu, Korea.

Fernández-Macías, E., Gómez, E., Hernández-Orallo, J., Loe, B. S., Martens, B., Martínez-Plumed, F., Tolan, S. (2018). *A multidisciplinary task-based perspective for evaluating the impact of AI autonomy and generality on the future of work*. AEGAP2018 Workshop at ICML 2018.

Gómez, E., Blaauw, M., Bonada, J., Chandna, O., and Cuesta, H. *Deep Learning for Singing Processing: Achievements, Challenges and Impact on Singers and Listeners*, Keynote speech at Music and ML workshop, ICML 2018. <https://arxiv.org/abs/1807.03046>

Porcaro, L., and Gómez, E. (2019). *20 Years of Playlists: A Statistical Analysis on Popularity and Diversity*. Proceedings of the International Society for Music Information Retrieval Conference, Delft, Netherlands.

Sturm, B., Iglesias, M., Ben-Tal, O., Miron, N., and Gómez, E. (2019). *Artificial Intelligence and Music: Open Questions of Copyright Law and Engineering Praxis*, Arts 2019, 8(3), 115; <https://doi.org/10.3390/arts8030115>

Tolan, S., Miron, M., Gómez, E., Castillo, C. (2019). *Why Machine Learning May Lead to Unfairness: Evidence from Risk Assessment for Juvenile Justice in Catalonia*, Seventeenth International Conference on Artificial Intelligence and Law, Best paper award.

Reports to which HUMAINT contributed

Craglia, M., et al., (2018). *Artificial Intelligence - A European Perspective*, EUR 29425 EN, Publications Office of the European Union, Luxembourg, JRC113826. <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/artificial-intelligence-european-perspective>

Gómez, E. (editor). *Assessing the impact of machine intelligence on human behaviour: an interdisciplinary endeavour*. Joint Research Centre Technical report. <https://arxiv.org/abs/1806.03192>

Gonzalez Vazquez et al., (2019). *The changing nature of work and skills in the digital age*, EUR 29823 EN, Publications Office of the European Union, Luxembourg, JRC117505. <https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/changing-nature-work-and-skills-digital-age>

10.7 HUMAINT Project team

Lead scientist: Emilia Gómez

Project team members: Vicky Charisi, Marius Miron, Songül Tolan, Marina Escobar-Planas, Bertin Martens

11 Understanding impact on AI on Society

11.1 Digital skills

Report: “Academic offer and demand for advanced profiles in the EU”, 2019¹⁸

This study aims at supporting the policy initiatives to ensure the availability in EC Member States of adequate advanced digital skills in a number of IT domains including Artificial Intelligence, High Performance Computing and Cybersecurity.

By making use of the Techno-Economic Segments (TES) analytical approach developed under the PREDICT3 project, the study collects data and builds quantitative indicators to provide a mapping of digital skills in the mentioned technological domains from two complementary perspectives: the existing offer of academic programmes (bachelor, master and doctoral programs), and the demand of profiles by the industry, as reflected by industry activity in the referred fields.



¹⁸ <https://ec.europa.eu/jrc/en/publication/academic-offer-and-demand-advanced-profiles-eu>

11.2 Data Governance Models (DIGITRANSCOPE)

The Digitranscope project¹⁹ of the JRC Centre of Advanced Studies has organised a workshop on data governance in October 2018²⁰ and submitted a paper to an international journal on the same topic.

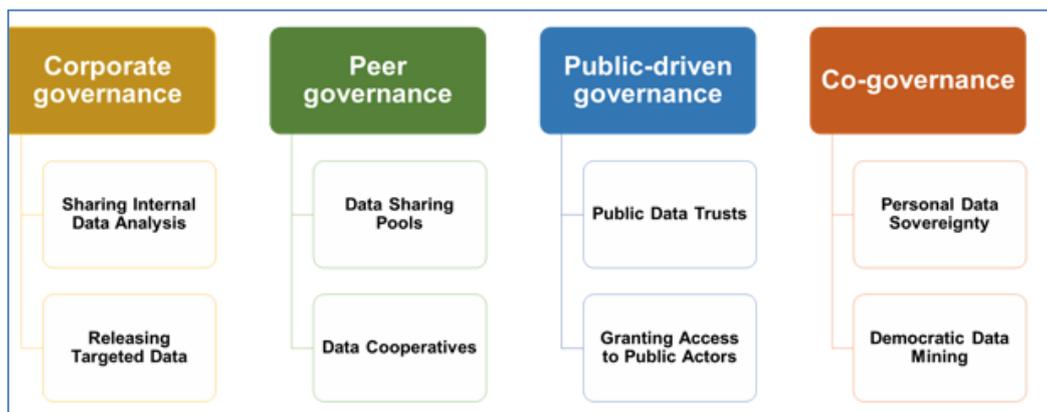
11.2.1 Emerging Models of Data Governance in the Age of Datafication

Data governance has become a key policy theme in Europe, but the lack of a shared vocabulary and established frameworks constrains the ability of scholars to contribute to the field. Major attention is placed to the hegemonic approach consisting of corporate online platforms collecting, analysing, controlling and financially exploiting massive amounts of personal data. However, other actors, from the public sector, academia and civil society, are progressively becoming involved in various forms of data governance. To increase knowledge about the variety of approaches currently being developed or imagined in Europe for governing data, we explored and systematised a wide range of resources that address different ways of accessing, controlling and generating value from personal data. Following a conceptual framework, we identified eight data governance models that we organised in four types: corporate governance, peer-governance, public-driven governance and co-governance. Our results indicate that corporate platforms hold most of the power to set the terms for data access and use in three models, while the remaining ones are more open to negotiations and to share decision-making power with other actors. Profit is the main value derived from data in corporate governance models, while the others pursue different objectives, including public service enhancement, public good and citizens' self-determination. The paper shows that scholars, policy makers and innovators are imagining and developing alternatives to the dominant model of platform capitalism. However, these alternatives are very often niche initiatives. More research is needed to investigate their feasibility, sustainability and actual outcomes.

11.2.2 Typology of Data Governance Models

The governance of digital transformation, and of major new areas such as AI, revolves primarily around the governance of data. To increase understanding of this emerging field, we have systematized different approaches to data governance currently implemented or imagined across Europe. Most of these models rethink and redress the asymmetries of power over data access/use between big data platforms and other actors (public bodies, civil society, citizens, SMEs and start-ups). Following a framework, informed by science and technology studies and the concept of governance, we came out with the following typology:

Figure 12. Typology of Data Governance Models



Source: JRC

¹⁹ <https://ec.europa.eu/jrc/communities/en/community/digitranscope>

²⁰ The workshop report is available at: https://ec.europa.eu/jrc/communities/sites/jrccties/files/jrc_digitranscope_report_-_oct_2018_data_governance_workshop-r_0.pdf

11.3 Participation in the JRC Collaboration with leading Science Centres & Museums

The main objective of the JRC Collaboration with Leading Science Centres & Museums²¹ is to inform a wide public about the work of JRC and, beyond that, to develop citizen engagement in EU and JRC initiatives. AI Watch participates in [Pilot Project 2: MuST Milano and Universiences Paris](#), which aims to organise activities about AI at the *Museo Nazionale della Scienza e della Tecnologia Leonardo da Vinci* (MuST) science museum in Milan and *Universiences* in Paris. These activities include Virtual/Augmented Reality (VR/AR) experiences as well as workshops in these museums, starting with the activities that will take place in MuST in 2020.

The VR/AR activities comprise three modules:

1. General introduction to AI, to provide general background knowledge using holographic screens.
2. Ethical aspects of AI, to be implemented as an AR experience (Tribunal).
3. Mobility in Europe in 2050, also including (semi)autonomous vehicles, to be implemented as a VR experience.

AI Watch contribution is mainly on the first module, where we are responsible to propose/indicate the material to include and work together with the MuST staff and our colleagues from E2 for the development of the experience. We have already proposed a possible outline for this experience, which is now finalized together with our JRC and MuST colleagues, and we are exploiting with them the existing AI Watch outcomes (the AI Watch timeline, the landscape dashboard, etc.). We also provide ad-hoc contributions, when asked, for the other experiences. The VR/AR activities will be further utilised during the workshops that will take place in the museums.

The workshops will be oriented around different AI topics. They will last about 2 hours and will involve up to 25 participants. The main target group will be secondary school students, with a possibility to include also teachers and specific groups of interest. It might also be possible to have shorter workshops for the general public or specific groups of interest. The workshops will be introduced through specific situations or experiences on a single topic per workshop, adapted to the workshop participants. The structure of the workshops will facilitate the possibility to discuss topics that spontaneously come up from the participants. At the end of the workshops, the audience will formulate answers and new questions about where they would put their limits and up to what extent they are willing to provide data in different circumstances.

²¹ <https://webgate.ec.europa.eu/connected/groups/jrc-collaboration-with-leading-science-centres-museums>

12 Conclusions

This report provides an overview of AI Watch activities in 2019. More detailed information is available in the different reports published by the project and mentioned in this report. In its first year, AI Watch has already contributed significantly to its main objective *to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe*. It has developed and proposed methodologies for data collection and analysis in a wide scope of AI-impacted domains, and has presented new results that can already support policy making on AI in the EU.

All AI Watch results and analyses are published on the AI Watch public web portal.²² A list of published AI Watch reports is available in Annex.

In the coming months AI Watch will continue collecting and analysing new information, it will provide updated results and will further improve its methodologies, where possible. AI Watch welcomes your feedback. This report will be updated annually.

²² https://ec.europa.eu/knowledge4policy/ai-watch_en

List of figures

Figure 1. AI History Timeline15

Figure 2. *AI Collaboratory* - AI systems vs task performance.....16

Figure 3. *AI Collaboratory* - Task progress17

Figure 4. AI Watch AI Landscape Dashboard19

Figure 5. Methodology to collect EU Member States National AI Strategies and initiatives22

Figure 6. AI investments in the EU Member States25

Figure 7. Announcement of collaboration Regione Lombardia and European Commission on AI Watch28

Figure 8. AI Watch overview of AI initiatives30

Figure 9. HUMAINT three goals32

Figure 10. Decision making process made by a data-driven algorithm33

Figure 11. Tasks and AI progress linked through cognitive abilities33

Figure 12. Typology of Data Governance Models37

List of tables

Table 1. AI investment highlights in 2018 for the EU28.24

Annex 1: AI Watch publications

Results of AI Watch 2019 activities are published in the following JRC publications.

Reports

- “Defining Artificial Intelligence – Towards an operational definition and taxonomy of artificial intelligence”
https://ec.europa.eu/knowledge4policy/ai-watch/defining-artificial-intelligence_en
- “AI Watch: Methodology to Monitor the Evolution of AI Technologies”
<https://ec.europa.eu/jrc/en/publication/ai-watch-methodology-monitor-evolution-ai-technologies>
- “TES analysis of AI Worldwide Ecosystem in 2009-2018”
https://ec.europa.eu/knowledge4policy/ai-watch/ai-landscape-2009-2018_en
- “Towards an AI Watch Index - Approach to indicators identification and AI Index construction”
(forthcoming, will be available on the AI Watch portal once published)
- “National strategies on Artificial Intelligence: A European perspective in 2019”
<https://ec.europa.eu/jrc/en/publication/ai-watch-national-strategies-artificial-intelligence-european-perspective-2019>
- “Estimating investments in General Purpose Technologies: The case of AI Investments in Europe”
https://ec.europa.eu/knowledge4policy/ai-watch/estimating-investments-general-purpose-technologies-case-ai-investments-europe_en
- “Methodology to Monitor the Uptake and Impact of AI Applications”
https://ec.europa.eu/knowledge4policy/publication/methodology-monitor-uptake-impact-ai-applications_en
- “Tracking the EU robotics market shares: data and methodology”
(forthcoming, will be available on the AI Watch portal once published)
- “Artificial Intelligence in public services - Overview of the use and impact of AI in public services”
<https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/ai-watch-artificial-intelligence-public-services>
- “Academic offer and demand for advanced profiles in the EU”
<https://ec.europa.eu/jrc/en/publication/academic-offer-and-demand-advanced-profiles-eu>
- AI Watch 2019 Activity Report
(the present report, will be available on the AI Watch portal once published)

On-line

- AI Watch public web portal
https://ec.europa.eu/knowledge4policy/ai-watch_en
- AI History Timeline
https://ec.europa.eu/knowledge4policy/ai-watch/timeline-visualising-ai-history_en
- *Aicollaboratory*
<http://www.aicollaboratory.org/>
- AI Landscape Dashboard
https://ec.europa.eu/knowledge4policy/ai-watch/topic/ai-landscape-indicators_en
- AI National Strategy Reports
https://ec.europa.eu/knowledge4policy/ai-watch/national-strategies-artificial-intelligence_en

Annex 2: AI Watch tasks and activities, and their leaders

- Landscape of AI in Europe: from Research to Market and Society (Giuditta De Prato)
- Evolution of AI technology (Emilia Gomez)
- Evolution of AI uptake (Massimo Craglia)
- Evolution of European market share in Robotics (Nestor Duch Brown)
- EU Member States National Initiatives on AI (Alessandro Annoni, Vincent Van Roy)
- Use and Impact of AI in Public Services (Gianluca Misuraca)
- AI Index (Giuditta de Prato)
- Portal development (Karen Fullerton)
- Monitoring Standardisation in AI (Stefano Nativi)
- Education and skills (Giuditta de Prato)
- Key enablers of AI (Stefano Nativi)
- Social perspective (Emilia Gomez)
- AI Watch project leader: Paul Desruelle

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
- at the following standard number: +32 22999696, or
- by electronic mail via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from EU Bookshop at: <https://publications.europa.eu/en/publications>. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.



EU Science Hub
ec.europa.eu/jrc



@EU_ScienceHub



EU Science Hub - Joint Research Centre



EU Science, Research and Innovation



EU Science Hub



Publications Office
of the European Union

doi:10.2760/007745

ISBN 978-92-76-19515-3